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THE NORTH CAROLINA GEOLOGICAL SURVEY

J. A. HOLMES, STATE GEOLOGIST

BULLETIN No. 19

THE TIN DEPOSITS

OF

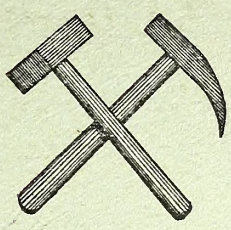
THE CAROLINAS

BY

JOSEPH HYDE PRATT, PH. D., MINERALOGIST

AND

DOUGLASS B. STERRETT



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LETTER OF TRANSMITTAL.

RALEIGH, N. C., May 1, 1904.

To His Excellency, HON. C. B. AYCOCK,

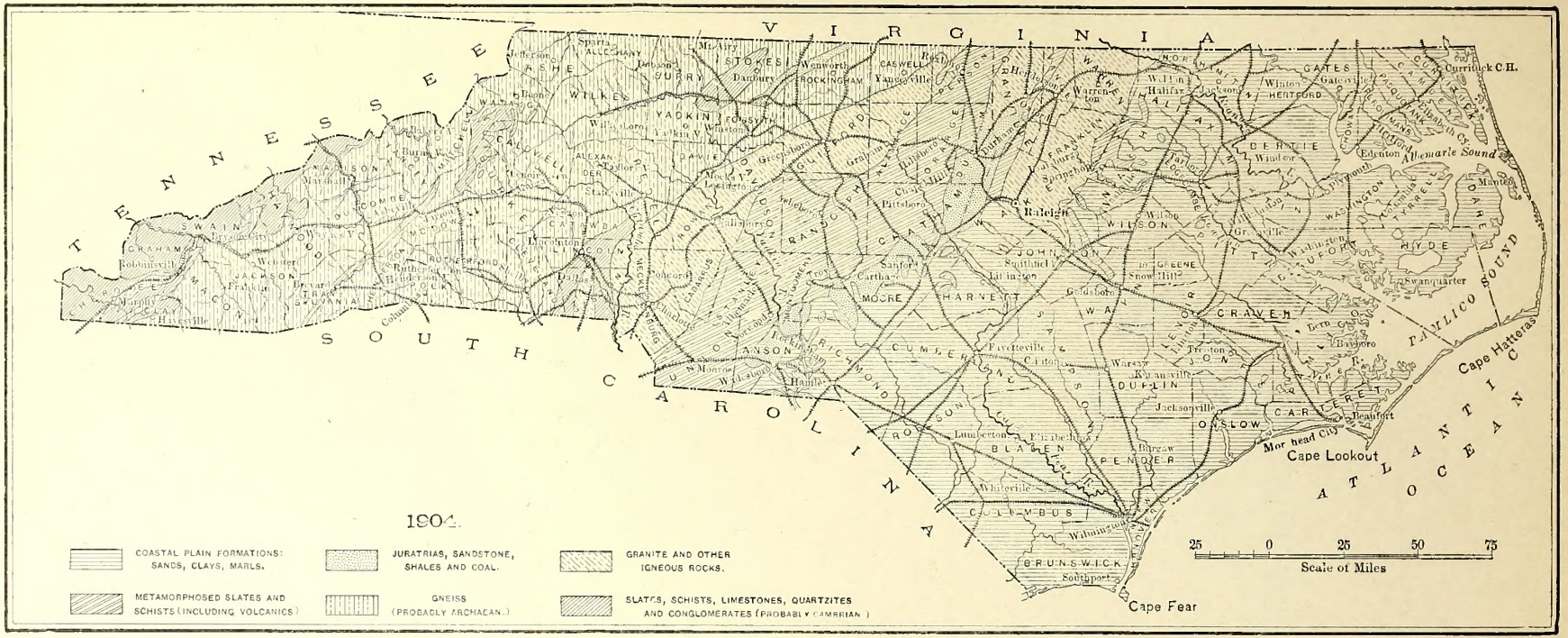
Governor of North Carolina.

SIR:—The interest that has recently been aroused in the occurrence of tin ore in the Carolinas has led to an examination of the deposits and the preparation of the present report on the Tin Deposits of the Carolinas, which I have the honor to submit for publication as Bulletin No. 19. In this report an attempt has been made to answer as fully as possible the various questions that have been raised regarding the extent and occurrence of the tin ore in the Carolinas, the economic value of the deposits, and the world's source of supply of tin.

Yours obediently,

J. A. HOLMES,

State Geologist.



MAP OF NORTH CAROLINA SHOWING THE DISTRIBUTION OF THE PRINCIPAL GEOLOGICAL FORMATIONS.

THE TIN DEPOSITS OF THE CAROLINAS.

BY

JOSEPH HYDE PRATT

AND

DOUGLASS B. STERRETT.

INTRODUCTION.

When one considers the amount of tin that is consumed each year and investigates the sources of supply of this metal, he begins to realize that it is an important question that has been raised as to where the world's supply of tin is to be obtained. During the past few years the yearly production has not been equal to the demand, and the accumulated stocks of tin that have been held in various countries have become very much diminished since 1896. Thus, while the demand for tin is increasing, due chiefly to the large growth of the canning industry and the use of tin boxes and cases in shipping sundry articles, the production has not kept pace with this demand. Approximately 43 per cent. of all the tin produced in the world is consumed in the United States, and until the past year there has been practically no production of this metal in this country. With the exception of the discovery of tin in Alaska, the ore deposits recently located in North and South Carolina are the only ones that have been discovered during recent years that have offered any chance of becoming commercial producers of this metal.

On account of the value of the metal, tin, it is possible to work very low grade ores, if they are in quantity. Usually there is but little difficulty in cleaning and concentrating a tin ore so as to obtain a nearly pure product. The tin mineral that constitutes the ore is cassiterite, a tin oxide represented by the formula, $Sn O_2$, and is a heavy mineral, having a specific gravity of about 6.5 to 7.

Considering the existing conditions in the tin industry, any discovery of tin like that of the Carolinas is of importance and demands

attention; and it would mean much to this country if commercial tin deposits could be opened up, so that we would not be entirely dependent upon foreign countries for our supply of this metal.

The discovery of tin ore in North Carolina near Kings Mountain was made in 1883, and, according to Mr. John Furman,* a mining man from Georgia, loose pieces of cassiterite were found lying upon the surface by a young man named Claywell, who was attending a school taught by Captain W. T. R. Bell. He was attracted to the mineral by its peculiar appearance and unusual weight; but was unable to determine its exact mineral character. Later these specimens were on exhibition at Boston, and Dr. Charles W. Dabney, who was present, noticed them, and upon testing same they proved to be the mineral cassiterite. Although some prospecting was done in the vicinity of Kings Mountain for tin ore, it was not until 1886 that any systematic prospecting was carried on. Early in that year Mr. John H. Furman spent a number of days examining the tin belt and found a number of samples of the tin ore, which were assayed at Ledoux & Co.'s laboratory in New York, and this firm later in the year retained Mr. Furman to make a thorough, systematic search of this region. In 1888 a 10-stamp mill was erected by Mr. Ledoux and his associates in which to thoroughly test the tin ore which was being developed; but, owing to litigation, work on the property ceased in the latter part of 1889. About the year 1892 work was begun on the Chestnut Hill property, but continued for only a portion of the year. Since then little or no work was done on the tin belt until 1903, when the Ross mine at Gaffney, South Carolina, was discovered. This has led to renewed interest in the Carolina tin belt, and considerable prospecting and development work is now being done at a number of places along the belt.

GEOGRAPHICAL LOCATION.

What may be called the Carolina tin belt extends from Gaffney, Cherokee County, South Carolina, in a general northeasterly direction across this county; the southeastern corner of Cleveland County, North Carolina, and across Gaston and Lincoln counties, North Carolina. The tin deposits found in Rockbridge County, Virginia, may be a continuation of the Carolina tin belt across Catawba, Iredell,

*Trans. N. Y. Acad. Sci., Vol. VIII, 1888-1889, p. 142.

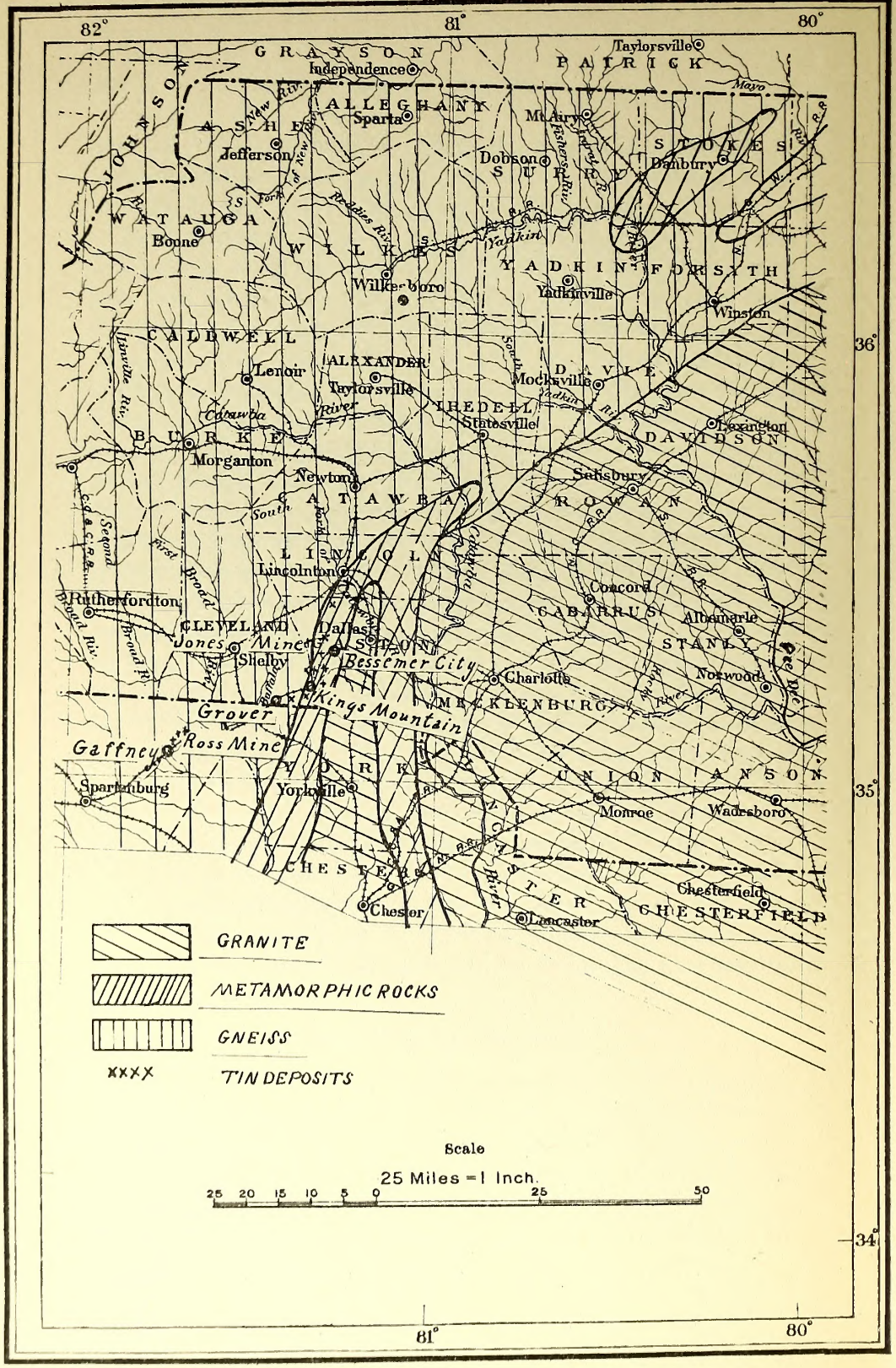


FIG. 1.—GEOLOGICAL SKETCH MAP SHOWING THE LOCATION OF THE CAROLINA TIN DEPOSITS.

Yadkin and Surry Counties, North Carolina. The general direction of the rocks carrying the tin ore is the same as those in Virginia, and the continuation of this direction from the Carolina deposits would approximately cross those places in Rockbridge County, Virginia, where tin ore has been found. The same rocks that are outcropping in Surry County, North Carolina, are also in this same line and have the same general direction. The principal locality in South Carolina where tin ore has been found is about one mile north of Gaffney on land belonging to Captain S. S. Ross. For a distance of 13 miles from a point about a mile northeast of the Ross mine no tin minerals have as yet been found. The next place in the belt where tin is known to occur is a short distance northeast of Grover, North Carolina, a station on the Southern Railroad. From this point tin ore has been found almost continuously for over 14 miles to within a few miles of Lincolnton, Lincoln County, North Carolina, and it is reported to have been found a few miles northeast of Lincolnton, but no authenticated record of this discovery could be obtained. No tin has thus far been found in North Carolina northeast of the Lincolnton locality, nor in Virginia until the Rockbridge County deposits are reached.

A general idea of the location of the Carolina tin deposits is given in the map, Figure 1. The principal deposits that have thus far been located are the Ross mine at Gaffney, South Carolina; the deposits in the vicinity of the town of Kings Mountain, North Carolina; on the southern end of Chestnut Ridge, about 2½ miles northeast of Kings Mountain; and on the John E. Jones plantation, 7 miles northeast of Kings Mountain.

The Southern Railroad passes over a considerable portion of the tin belt, following almost the general direction of the formation from Kings Mountain to Gaffney. At the former place the railroad turns sharply to the east, crossing the tin belt, which continues toward the northeast. Thus, any commercial deposits that may be developed will have good railroad facilities, not being more than a few miles from the railroad. Those on Chestnut Ridge are not over two miles from the railroad, and the ore mined could easily be hauled to the railroad at small expense. If the Jones deposit proves to contain tin in any large quantity, it would still be profitable to haul the ore to the railroad at

Bessemer City, a distanee of about 4 miles, if it did not prove feasible to build the railroad to the deposits.

GEOLOGY.

The section of North Carolina and South Carolina in which the tin belt oeeurs is elose to the border of the large area of Archean gneisses whieh extend over a large portion of the western part of North Carolina and the northwestern portion of South Carolina. Bordering these gneisses on the east, there is a series of granites and other igneous roeks extending from Cherokee County, South Carolina, aeross Mecklenburg, Cabarrus, Rowan, Davidson, Guilford, Caswell and Person Counties, North Carolina, whieh have a general north to northeast direction. At the extreme southern portion of North Carolina, and extending into South Carolina, there is between these granites and gneisses a band of metamorphic rocks consisting of slates, schists, limestones, quartzites and conglomerates whose age is unknown. These oecur quite extensively developed in Cherokee County, South Carolina, and in Gaston, Lincoln and Catawba Counties, North Carolina, and extend for a very short distance into Iredell County, North Carolina. No more of these rocks are observed in this northeast direction until they again outerop in the northeastern portion of Yadkin County, extending nearly across Stokes County and almost to the Virginia line. They are in every way identieal with those found further south and represent the same geological formation. Penetrating up into these rocks in Gaston and Lineoln Counties, North Carolina, there is a mass of granite which is from five to ten miles wide. The sehists vary considerably in character, sometimes being very silieeous and having a gneissoid structure. The general strike of these metamorphic roeks is northeast; and it is in this belt of rocks in North Carolina that the tin ore is found. The general strike of the pegmatitic dikes and veins carrying the tin is approximately the same as that of the metamorphic rocks, N. 25° E., but near the South Carolina line there is a rather sharp bend to the westward, so that from there to Gaffney, South Carolina, the direction of the tin belt is about N. 55° E., and it leaves the schists to the east and passes through the Archean gneisses. The rocks in the vicinity of Gaffney, South Carolina, are almost entirely gneisses, similar to those found in North Carolina to the west of the metamorphic rocks and which have been

referred to as the Archean. There are, then, rocks of two distinct geological periods in which the tin veins have been found: (1) Those associated with the Archean gneisses, which are found in the vicinity of Gaffney, South Carolina; and (2) those associated with the schists, which are of a later period, and with which most of the North Carolina tin is found. The ore at the Jones mine, 7 miles northeast of Kings Mountain, is in greisen veins that occur in a gneissic rock, which may be a portion of the Archean gneisses to the west.

As has been stated above, the main country rocks are for the most part crystalline schists and gneisses, the former being micaceous, chloritic and argillaceous, and the latter micaceous and hornblendic. The strike of the schistosity of these rocks is usually in a general northeast direction and they dip for the most part at very steep angles to the westward. The veins in the gneisses are dipping toward the east at very steep angles.

The Kings Mountain region of North Carolina is geologically situated in a band of metamorphic rocks composed of slates, schists, limestones, quartzites and conglomerates whose age up to the present time has not been definitely determined. The width of this belt near Kings Mountain is about 10 miles and extends in a direction about N. 10° to 20° E. Just east of Lincolnton, Lincoln County, it joins another band of similar rock, the two being separated east of Kings Mountain by a mass of granite. To the west of these metamorphic rocks are the Archean gneisses, with which the tin veins of Gaffney, South Carolina, are associated. The strata of these metamorphic rocks are tilted at very high angles to nearly vertical, and in the resultant alteration and erosion to which they have been subjected, the quartzites have resisted these influences the most, so that they now form the top of the peaks and ridges such as Kings, Crowders and Anderson mountains, which rise 500 to 1,000 feet above the average elevation. It is undoubtedly the mass of granite which is to the east that has tilted these metamorphic rocks and thrown them into their present position.

There are a number of amphibolite dikes that have been observed cutting these metamorphic rocks, but they have made very little change in the position of the schists through which they penetrated beyond a metamorphic action. These sedimentary rocks were tilted

into their present position before the intrusion of these dikes, which are following partly the lamination of the schists and their general trend; but in a few instances are cutting across the schist. In two or three instances where these dikes are cutting across the schists, there are approximately parallel to them veins of tin ore. Pegmatitic dikes are also common throughout this belt of metamorphic rocks in North Carolina and in the gneisses further to the west in South Carolina. They could be followed almost continuously from three miles above Grover, North Carolina, to the Jones mine, 7 miles northeast of Kings Mountain. In one place, a short distance below Kings Mountain, North Carolina, the pegmatitic dike was all of 200 feet wide. They follow in many cases the planes of lamination of the schist which represent lines of least resistance. Where the pegmatitic dikes are cutting across the schists, they may be following old fractures that were produced at the time of the intrusion of the amphibolite dikes.

About one-half mile below Kings Mountain the pegmatitic rocks begin to outcrop very boldly and continue in this way nearly to Grover, North Carolina, a distance of 7 miles. This mass of pegmatite varies a good deal in width in this distance, from twenty-five to six hundred feet. Just in the northern edge of the town of Kings Mountain there is another strong outcrop of the pegmatite, but from this point there is but little seen of the pegmatite northeast until Ramseur's mill is reached. Here the pegmatite has a width of about 200 feet.

A cross-section of the tin belt in the vicinity of Kings Mountain would show the following sequence: hornblende-gneiss on the western boundary, followed on the east by schists which are in many places very badly decomposed; then a narrow bed of limestone which is more or less siliceous; then quartzite; another bed of limestone; quartzite; schist; to the granite on the extreme eastern portion of the belt, having a total width of about 10 miles.

The term greisen is given to a granitoid rock composed essentially of quartz and muscovite or some related mica rich in fluorine, and it is associated with this type of rock that the cassiterite, when occurring as an ore of tin, is nearly always found.

The tin ore of the Carolina belt occurs in greisen veins that are for the most part in the main mass of mica schist adjoining the gneiss

on the west, and which extends in almost a continuous belt from the South Carolina line to a few miles northeast of Lincolnton, North Carolina. The width of this schist formation is approximately one mile and is bordered on the east by the limestone. At the Jones mine, 7 miles northeast of Kings Mountain, the rocks are gneissic in structure. In South Carolina, where the belt has made a bend toward the west, the tin ore occurs in the greisen veins that are in gneiss.

Where the tin occurs in the large pegmatitic dikes, it seems to be in greisen veins on the boundaries of these where the fumarole action would be the greatest, and probably within the larger masses of pegmatite, where greisen veins may have formed in shrinkage cracks, developed during the cooling of the magma. It has been observed, however, for the most part, in lens-shaped masses of greisen, such as are commonly found in laminated metamorphic rocks, especially schists, when pegmatitic dikes are intruded into them and which are often called "augen." In these lenses in the schist that carry tin there was usually no feldspar present, but similar lenses were observed in the schist that did contain considerable feldspar. These, however, contained little or no tin.

In the vicinity of Gaffney, South Carolina, the greisen veins carrying tin, which are in gneiss, all contained more or less feldspar which was nearly or completely altered to kaolin.

MINERALOGICAL AND CHEMICAL CHARACTER OF THE ORE.

Cassiterite, the tin-bearing mineral of the veins, is an oxide of this metal whose formula is $Sn O_2$ and contains theoretically 78.6 per cent. of metallic tin. When chemically pure this mineral is nearly white in color, but it usually contains more or less ferric oxide, and its color varies from reddish to brown or black, varying with the percentage of iron. Arsenic is also occasionally found in this mineral, and an arsenical cassiterite is usually yellowish in color.

The mineral is tetragonal in its crystallization, and while in certain localities it is sometimes crystallized, it more often is granular and in rough masses, especially where it is found in commercial quantity. The crystals are usually prismatic and are often twinned both as contact and penetration twins. It is a brittle mineral, having an imperfect cleavage, and breaking usually with a subconchoidal fracture.

Its hardness is from 6 to 7 and its specific gravity varies from 6.16 to 7.1, according to the amount of impurity in the mineral. When the percentage of iron is low the crystals are nearly transparent, but become nearly opaque with the increasing percentage of iron oxide. Its lustre is adamantine but the crystals are usually splendant.

There are three varieties of cassiterite that are recognized as follows:

1. Ordinary or tin-stone, which is the crystalline and massive variety obtained directly from the vein or from the broken-down material just below the vein.

2. Wood-tin, which is in botryoidal and reniform shapes with a concentric structure which internally is fibrous but very compact. Its color is brownish, but of mixed shades, giving it the appearance and color of dried wood.

3. Stream-tin is the mineral in the form of sand, as it is found concentrated along the beds of streams and in the gravels below the veins.

None of the wood-tin has been found in the Carolina belt, but the ordinary or tin-stone and stream-tin occur abundantly. Crystallized cassiterite, while not common, has been found, the better crystals having been obtained thus far from the Jones mine, in North Carolina. The only face that has been observed on any of these crystals is the pyramidal face, *s* (111). The crystals occur both simple, and twinned with *e* (101), as the twinning plane, and are represented by Figs. 2 and 3. The crystals are small, from a quarter to half an inch

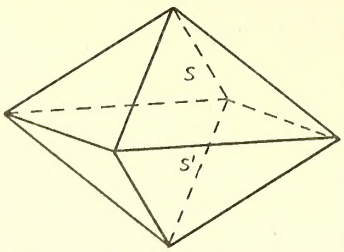


FIG. 2.—CRYSTAL OF CASSITERITE.

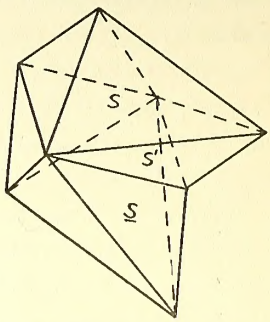


FIG. 3.—TWINNED CRYSTAL OF CASSITERITE.

in length, and are usually of a black color. They are fairly well developed, with most of the edges sharp and distinct. Some, however,

are considerably elongated, as represented in Fig. 4. All the faces are more or less corroded and striated. Rough, partially crystallized cassiterite is found at many places throughout the belt, and from the Faires property, just south of Kings Mountain, one rough crystallized fragment was found which weighed nearly one-half pound. Small but well-developed pyramidal crystals have been found in the sands

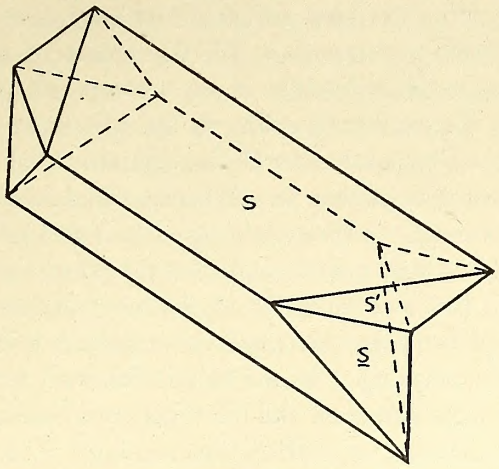


FIG 4.—ELONGATED TWINNED CRYSTAL OF CASSITERITE.

taken from alongside of the road on the M. V. Hovis land. Some of the crystals are simply pyramids and extremely regular in their development, while others are elongated and twinned. The color of the cassiterite found in the Carolina belt varies from black to almost colorless, the common color being a dark brownish-black, and more rarely a light grayish.

Partial analyses have been made of two varieties of the cassiterite found in and about the town of Kings Mountain, North Carolina, one a light grayish and the other a dark brown. The results of these analyses by Professor C. W. Dabney* are given in the table below:

PARTIAL ANALYSIS OF CASSITERITE.

	LIGHT GRAYISH.	DARK BROWN.
Stannic oxide	94.70	82.99
Tungstic oxide	.92	1.14
Sulphur	Trace	0.46
Arsenic	Trace	Trace

*Bull. 74, U. S. Geol. Survey, p. 35.

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As is seen from the above, the percentage of stannic oxide in the light grayish variety is much higher than that in the dark brown, and this is due probably to the larger per cent. of iron that was in the latter sample. These percentages of stannic oxide would correspond to 74.41 per cent. of metallic tin in the light gray sample and 65.21 per cent. in the dark brown. A sample of the pure cassiterite from the Jones mine has been analyzed and gave 89.95 per cent. of stannic oxide which corresponds to 70.70 per cent. of metallic tin.

There is a noticeable difference in the occurrence of the cassiterite in the veins of the southern portion of the belt from those towards the north. At the Ross mine, near Gaffney, South Carolina, the cassiterite is associated with more or less feldspar, which has been partially kaolinized and in some cases completely altered to kaolin, with muscovite mica and but little quartz; and so at the present stage of the development work but little solid ore is obtained, the cassiterite being readily separated from the vein material or gangue minerals without the need of any crushing. As the belt is followed north, however, quartz becomes more abundant and the veins are composed principally of quartz with mica and cassiterite, thus making a firm, compact ore. This latter occurrence would make a true, typical greisen. In this section of the belt it is common to find scattered over the surface boulders from a few pounds to one hundred and fifty or more pounds in weight composed of quartz, mica and cassiterite. The tin, as a rule, is imbedded more in the mica than in the quartz, and the mica in the greisen veins containing tin has a pale, apple-green color, and is fluoric. There is a small amount of partially altered feldspar occasionally found associated with these veins in the schist. This variation in the occurrence of the tin is due to the country rocks in which the veins occur, those to the north being for the most part in the mica and quartz schists, while those at the Ross mine are cutting a hornblende-gneiss. This variation is discussed further under Origin of the Tin Ore.

ASSOCIATED MINERALS OF THE CASSITERITE.

A small amount of jet-black tourmaline in rough prismatic crystals and minute needles has been found directly associated with tin, both in the quartz and in the feldspar veins; but it is rare to thus find it in the veins with the tin. It is, however, very commonly found

just to one side of the vein in the schist or gneiss and in some instances represents a tourmalinization of the wall rock. A little magnetite is also occasionally found. Thus far no fluorite or any of the tungsten minerals have been identified in these veins, although a fraction of a per cent. of tungstic oxide was obtained in the analysis of the cassiterite.

Pyrite, an iron sulphide, is found to some extent in the schists, but thus far it has been observed only very sparingly directly associated with the tin in the greisen veins. Chalcopyrite, a copper iron sulphide, has been reported by Mr. John H. Furham,* as occurring in some of the deeper workings made for the tin; and Dr. A. R. Ledoux† reports arsenopyrite (mispickel) as an associate of the tin.

In the concentrates of cassiterite obtained from the washing of the soil and gravel at various places along this belt, there is more variety in the associated minerals found with the tin. The associated minerals of the stream-tin are magnetite, ilmenite (or menaccanite), garnet, monazite, tourmaline, quartz, a little pyrite, and very sparingly chalcopyrite. Of the above the monazite and garnet are confined principally to the concentrates obtained from the breaking down of the tin veins occurring in gneiss. The monazite was observed in considerable quantity in the fine concentrates from the stream-tin obtained from the gravels in the vicinity of the Ross mine. It is in these same gneisses, in Cleveland, Burke, Lincoln, Rutherford and McDowell Counties, North Carolina, that the monazite which is mined commercially, originated. Occasionally there is a considerable percentage of monazite found in the concentrates with the tin, and one lot of concentrates obtained from the Ross mine that was tested contained 55 per cent. of cassiterite and 20 per cent. of monazite besides considerable garnet.

Regarding the ilmenite, which is found so abundantly associated with the tin in the gravels, it is to be noted that little or none of this mineral has been observed associated with the tin in the veins. There are, however, pegmatitic veins which carry a considerable amount of ilmenite, but such veins carry little or no cassiterite.

There are a number of the associated minerals of the cassiterite, as tourmaline, ilmenite (or menaccanite) and magnetite that are being

*Trans. N. Y. Acad. Sci., Vol. VIII, 1888-1889, p. 144.
†Eng. and Min. Jour., Vol. XLVIII, 1889, p. 521.

mistaken for the tin mineral. Tourmaline can generally be distinguished readily from the tin by its low specific gravity of 2.98 to 3.20, while that of the tin is about 7. It is not so easy to recognize the tourmaline by this property when it occurs in the quartz gangue, but it can often be at once identified by its triangular cross-section. The magnetite and ilmenite are much closer in specific gravity to the cassiterite, the former having a specific gravity of 5.16 and the latter of 4.5 to 5. The magnetite can readily be determined by its magnetic properties, but the fragments of ilmenite often closely imitate cassiterite and it is occasionally necessary to test the mineral to definitely determine which it is. If, however, it can be compared directly with known pieces of cassiterite, there will be little difficulty in distinguishing the lighter weight of the ilmenite.

The cassiterite can readily be determined by means of the blow-pipe test, by taking a very small amount of the very finely powdered mineral, mixing it thoroughly with six or eight times its volume of sodium carbonate, and a small amount of powdered charcoal, and then fusing this mixture on charcoal before the blow-pipe, when it is readily reduced, giving a button of metallic tin.

The position of the cassiterite in the vein varies considerably. In some instances, as in a 2½-foot dike at the Jones mine, the tin is rather evenly distributed throughout that portion of the vein in which it occurs; while in others, as at the Ross mine, the tin is concentrated in seams which are for the most part close to the hanging wall, which is toward the east. It is also to be noted that most of the tourmalinization that was observed was to the east of the tin-bearing veins. There is also a great variation in the percentage of the tin mineral in the vein, there being some portions that are absolutely barren, while other portions carry a high percentage of cassiterite, and still others were containing only a moderate amount. This makes it very hard to determine the actual percentage of tin in the vein without making a large mill test.

Many of these lenses of greisen, as they were followed downward, pinched out or narrowed to a thin seam, but usually before one gave out another was encountered.

PERCENTAGE OF CASSITERITE IN THE VEINS.

In order to obtain some idea of the percentage of cassiterite that the veins contained, a sample was taken from the 2½-foot vein at the Jones mine, and this gave on crushing and panning a concentrate of practically pure cassiterite which represented 5 to 6 per cent. of the vein. This would be equal to about 3½ per cent. metallic tin. Such an ore carrying this percentage of tin would, if in quantity, make a very profitable proposition. Favorably located deposits have been worked that did not carry over one per cent. of this metal.

While the above results may be accurate for the particular part of the vein from which the sample is taken, it does not really represent the average of the tin ore at the Jones mine, and this can probably be determined only by a mill test of a quantity of the ore. It will be found that even those that are very familiar with sampling would be unable to select from a pile of ore two samples which would agree with each other in respect to the amount of tin that they contain, and this is also true in sampling veins where only small quantities are taken. Dr. Ledoux, in connection with his work on the tin deposits in 1888, shipped to England two car-loads of ore from the Kings Mountain locality which were selected by a Cornishman, who endeavored as nearly as possible to obtain an average of hand-dressed ore. The returns received from these car-load lots of ore showed one to contain 2.5 per cent. and the other 1.5 per cent. of metallic tin. From his tests on the vein ore, he was of the opinion that large quantities of hand-assorted ore averaging one per cent. of metallic tin could be obtained and relied upon. The gravels in this same vicinity were also extensively tested, and, as stated by Dr. Ledoux, they operated on the bottoms and on the hill-sides along the creek and in the branches flowing into the creek. The richest deposits were found on these branches, but their superficial area was small. The results of this test showed these gravels to contain from 1.5 to 2.1 pounds of metallic tin per cubic yard. These concentrates, however, were largely contaminated with garnets and iron minerals, so that sand, washed clean, as much as possible without using a magnetic separator, varied considerably in the amount of metallic tin which they contained, their tin contents varying from 11.22 per cent. to 64 per cent. The gravels in this vicinity are not nearly as rich as those

near Gaffney, South Carolina, where the tin in the alluvial deposits is the result of breaking down of feldspathic veins in which the feldspar has been entirely decomposed and has readily freed the tin ore; while in the more northern portions of the belt, where the tin is more closely associated with the quartz and mica, in the breaking down of the veins it has been left more as boulders and fragments rather than as loose pieces of cassiterite in the soils and gravels.

The alluvial deposits of the Ross Mine, Gaffney, South Carolina, have been estimated, from the various tests that have been made, to average in the neighborhood of 25 pounds per cubic yard.

It is to be noted, however, that with the exception of the Cornish tin mines, nearly all the world's production of tin is obtained from alluvial deposits and not from vein formations. The foreign gravel deposits are usually much more extensive than those in the Carolinas and are more remote from the original veins. These are described on pages 36 to 40.

DEVELOPMENT WORK.

Ross Mine.—The principal development work that has been done on the tin belt is at the Ross mine, one mile nearly east of Gaffney, South Carolina. The tin ore was first observed in 1902 as small broken crystals in the soil, which were exposed by the uprooting of a large tree. As soon as the specimens were identified as cassiterite, the soil was tested by panning and found to contain a considerable quantity of this mineral. It was found on the slope of a hill which rises about 60 feet above the level of the stream, and all over this slope of the hill the tin was found in the soil and gravels. Near the top of the hill a shaft and an open pit were sunk, which cut into the saprolitic rock, in which were found saprolitic-pegmatitic dikes, carrying more or less tin ore. This pit was about 20 feet below the surface, 20 feet long, with a number of drifts running from it following on different seams containing tin. The shaft extended 9 feet below the bottom of the pit. Wherever the tin was found in place it was associated for the most part with feldspar, which was largely kaolinized, thus permitting the concentration of all the tin ore by hydraulic processes to a depth of at least 30 feet and probably considerably deeper.

The tin occurs in streaks, or seams, in the saprolitic pegmatite, which is dipping about 50° toward the east and close to the hanging

wall. The tin was found to continue to the lowest depth worked. In these workings there were a number of narrow pegmatitic dikes or lenses, all of which carried tin.

As these pegmatitic dikes were followed toward the southwest by the drifts they were found to be cut off in a distance of about 20 to 30 feet by a slickenside face which undoubtedly represents a line of faulting. The extent of the displacement was not determined.

Just above this shaft and pit and about 400 feet from the stream, a shaft 40 feet in depth was sunk and trenches were cut across the supposed strike of the veins, but there was only a small amount of tin obtained, although one fragment was found weighing about 3 pounds that was nearly pure cassiterite. None of the pegmatitic dikes were encountered in this work. This result was to be expected and is due to the faulting.

Numerous pits and trenches have been made from here to the stream and all showed the presence of tin ore, some carrying only about 12 pounds to the cubic yard, and some carrying as high as 75 pounds. The average for all this soil and gravel will be about 25 pounds per cubic yard.

At the stream a trench was run back into the hill for about 40 feet, following on bed rock. About the bed rock there was a stratum of gravel 1 to 3 feet in thickness overlain with soil which was 2 feet thick at the lower end of the trench and 6 to 8 feet at the upper end. Both the gravel and soil carried a good quantity of tin ore.

The area over which the cassiterite has been found in the soil and gravels is about 1,000 by 600 feet, and all of this material will undoubtedly pay to wash for this mineral. This alluvium varies in depth from a few feet to 8 or 10 feet, and it should all be treated hydraulically. There is a sufficient water supply close by for this purpose.

In tracing the float-tin from the Ross mine it was found almost continuously for half a mile southwest and for one and one-half miles in a direction about N. 55° E.; but no deposit of any importance has thus far been located. From this point no more tin has been found until a point was reached about 3 miles above Grover, North Carolina, a total distance of about 13 miles, in which there is no authentic record of any tin ore having been found. Pegmatitic dikes

have, however, been observed quite extensively developed in this intervening area and they are especially prominent just above Grover, North Carolina. It is probable that more systematic prospecting will reveal deposits of cassiterite in this portion of the belt. From this point tin ore has been found almost continuously to a mile or so above Lincolnton, a total distance of about 28 miles, although the principal deposits are at a distance of 7 miles northeast and southwest of Kings Mountain. It is near Grover, North Carolina, that the general direction of the belt changes from N. 25° E. to N. 55° E.

The next point at which any work has been done for tin is about 3½ to 4 miles southeast of Kings Mountain, where a cut has been made about 6 feet deep on the edge of a mass of pegmatite. These rocks carried cassiterite in small particles, and could be traced by means of surface pieces for a distance of about 100 yards. At another point, about one-half mile to the north, good ore was found as float just below a large mass of amphibolite rock. A trench had been dug below this amphibolite, which penetrated through mica schist and encountered a tin-bearing greisen.

In prospecting for tin in North Carolina where the pegmatitic dikes are not decomposed to any considerable extent, it has been the custom to sink a shaft in the schist just to one side of the pegmatite and then cross-cut the pegmatite from the bottom of the shaft. In many instances the schist is more or less decomposed and is very readily worked without any blasting.

Ledoux Property.—Two and a half miles northeast from this point is the Ledoux* tin property, which was worked quite extensively some years ago. A number of prospect trenches and shafts showing the existence of tin ore were made on the contact of the pegmatite and schist and others entirely within the pegmatite. There were three cross-cut trenches made which pass through the pegmatite to schist on the east and two other trenches that followed along the contact. From one of these latter a shaft was sunk, which is now partially filled up. The strike of these masses of pegmatite was N. 25° E., and then followed to a certain extent the lamination of the schists. Their dip, however, was nearly vertical. Just west of the old mill-site a shaft was sunk which opened up a body of good ore. In digging

*Eng. and Min. Jour., Vol. 48, 1889, p. 521.

the foundation for the mill it was reported that good ore was uncovered. A short distance to the south of the mill there has also been considerable prospecting done by means of trenches and shafts, which were generally made where float-tin was found in boulders. In the bottom of one of these shafts chalcopyrite is reported to have been encountered after working through a number of feet of the tin ore. Arsenopyrite (mispickel) has also been found associated with the tin in the Ledoux property. This is somewhat similar to the Cornwall deposits, where their work first penetrated through a body of tin ore, then into copper ore and again into tin ore. One thing to be noticed in connection with the deposits at this point is that the vein, which is nearly perpendicular, or dipping a few degrees to the east, is cutting across the lamination of the schist which is dipping toward the west.

About half a mile below the mill a great deal of float-tin has been found in boulders on the summit of a small hill, and the greater part of this was hauled to the mill for treatment. The greisen outcrops on top of this hill and small particles of tin ore were observed in some of the boulders and fragments broken off. A large trench had been cut in the pegmatite, but it apparently failed to reveal the source of the rich boulders of greisen.

In a recent communication, Dr. Ledoux* says regarding the work that was done in 1888 and 1889 under his direction on these tin deposits, that the rock was tested from various openings where they gave indication of containing tin, and that without any sorting they yielded from 0.3 per cent. to 0.6 per cent. of metallic tin. With ordinary negro laborers who were simply instructed to throw in one pile all pieces which appeared to contain tin, and reject the others, they sorted the ore up to a grade which yielded from 0.75 per cent. to 1.10 per cent. of metallic tin. It was found impossible to sample the deposits by hand or even to determine the average percentage of tin on the dumps where the work was being carried on, and for that reason a working plant consisting of a 10-stamp mill with vanners, double-decked buddle, and burlap sluices was erected. A number of holes were put down with the diamond drill, principally for determining the character of the strata and whether the greisen extended to any considerable depth, which was found to be the case.

*Letter to Joseph Hyde Pratt, dated New York, May 6, 1904.

Adjoining the Ledoux property on the north is what is known as the limestone tract, deriving its name from the fact that there is considerable limestone on the property. There has been a small amount of float-tin picked up as fragments and in small greisen boulders. No ore has been found thus far in the limestone.

Faires Property.—On the E. C. Faires plantation, which is near the southwestern boundary of the town of Kings Mountain, considerable tin ore was found at a number of places 100 yards or so apart, which are about one-fourth of a mile southeast of where the town boundary line crosses the track of the Southern Railroad. There are a number of large masses of pegmatite outcropping here on the surface. About a quarter of a mile to the southwest, where this property joins the Weir plantation, a little tin ore has been picked up in some of the gulleys. As the pegmatitic dikes were followed in this direction they became wider, increasing from 40 feet on the Faires property to about 200 feet on the Weir property. If there is any tin associated with these large masses of pegmatite, it is probably in small quantity, as a casual prospecting failed to reveal any.

Falls Property.—To the northeast of the Faires plantation a small amount of work has been done on the Mrs. Lizzie Falls place on the opposite side of the branch from where the tin ore was found on the Faires place. A number of shafts were sunk and ditches cut; but few of them showed any tin ore. Considerable rich ore was encountered in one of these shafts, about 4 feet from the surface; but it gave out in a few feet, due to the pinching out of the vein. The seams of greisen were from 2 to 8 feet in width, following the lamination of the schists. The other shaft that was sunk, while it did not show as rich bunches of ore as the first one, was in ore at the bottom. Fig. 5 is a map of the country in the immediate vicinity of Kings Mountain.

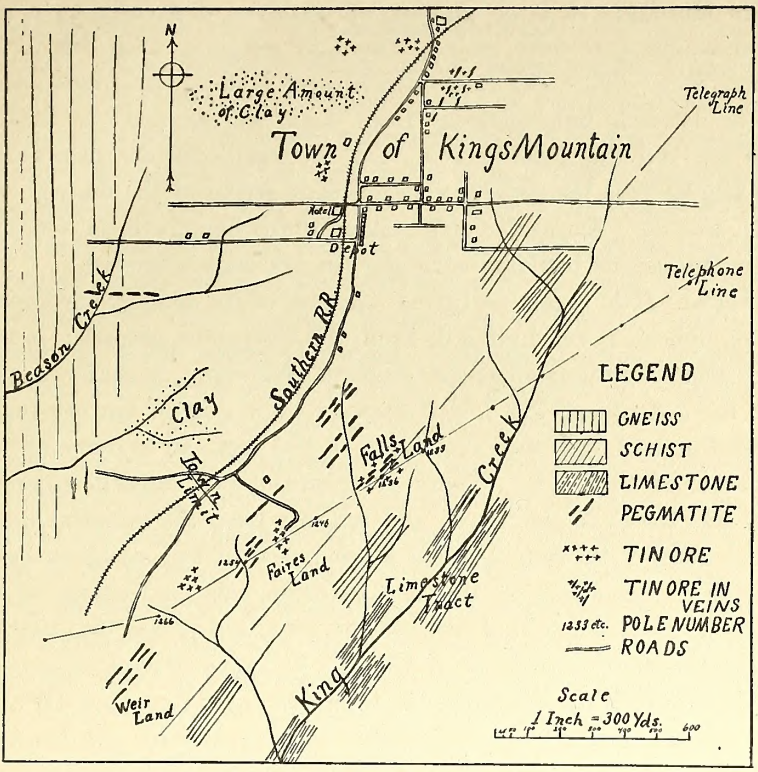

FIG. 5.—MAP OF THE KINGS MOUNTAIN TIN REGION.

The next place where cassiterite has been found in any quantity is in the northern part of the town, about 100 yards south of where the road crosses the railroad track. A number of small masses of greisen were observed containing more or less cassiterite. The mineral is in small pieces from the size of a grain of sand to that of a pea. This greisen can be traced across the Rudisill lot and is observed in the street beyond.

Fifty yards to the west of the railroad-crossing a small amount of float-tin has been picked up and near by small boulders of greisen have been observed. For a distance of 50 yards to the west tin ore can be picked up here and there over a considerable part of the surface.

Carpenter Property.—Following towards the northeast to the southern end of Chestnut Ridge, about 2 to 2½ miles northeast of Kings Mountain, on the property of Mr. M. M. Carpenter, of

Kings Mountain, a large number of boulders of greisen have been found which were very rich in tin, and weighing from 50 to 150 pounds each. The dike from which these boulders originated could not be located, but, judging from their appearance, it must be close by, and this locality is a very favorable one for prospecting. The schists have the general characteristic strike of the district, that is, N. 25° E. A quarter of a mile still further north, on Chestnut Ridge, numerous boulders carrying tin ore were observed.

Chestnut Hill Vein.—A little to the east of the summit of Chestnut Ridge, and about one-half mile from the Carpenter property, is what was formerly designated as the Chestnut Hill vein. A shaft was sunk here for a depth of 122 feet, following on a vein of tin ore that is reported to be 7 feet wide at a depth of 100 feet and to carry about 3 per cent. of tin oxide. There are contradictory reports regarding what was found in this shaft, and judging from the material that is on the dump pile, there was not a great deal of tin ore taken out of the shaft. According to Mr. J. C. Horton, who had charge of this work, the shaft penetrated through the vein, and it was the intention to sink this shaft to a depth of 130 feet and then drive a cross-cut to the vein. No work has, however, been done here for about 10 years, and, as the shaft was full of water, nothing definite can be stated regarding the conditions existing in the underground workings.

Ormond Property.—On the north end of Chestnut Ridge, on the property of Mr. J. J. Ormond, which is 3 miles northeast of Kings Mountain, considerable tin ore has been found in greisen boulders. It is reported that a trench made here encountered the greisen in place; but this is now filled up, so that nothing of this vein could be seen. The boulders observed were very similar to those encountered on the southern end of Chestnut Ridge, and this is also a favorable place for prospecting.

Hovis Property.—Only a few fragments of tin have been found in the next one and a half or two miles from the Ormond locality; but on what is known as the White lot, which adjoins on the north the M. V. Hovis place, boulders of greisen again become prominent, and these contain more or less cassiterite. On Mr. M. V. Hovis' property tin ore is found in fragments and boulders of greisen near the road and are constantly being plowed up in the fields. In the

gutters alongside of the road considerable black sand has been concentrated, consisting chiefly of cassiterite, magnetite and ilmenite.

Ramseur Mill Property.—About a third of a mile northeast is the Ramseur mill property, where a large pegmatitic dike is outeropping. Considerable cassiterite has been found as float and a trench cutting across this pegmatitic dike exposed a portion of this rock that contained cassiterite. The ore occurred near the contact of the pegmatite. It was very rich, and is another one of the places along the belt that is favorable for more thorough prospecting. There is a great deal of ilmenite, which occurs principally in flattened plates, found scattered over the surface of the field and on a road within 100 feet of the trench from which the cassiterite was obtained.

Jones Mine.—One of the most promising deposits of tin ore to the northeast of Kings Mountain is on the John E. Jones plantation, which is 7 miles northeast of Kings Mountain and 3½ miles a little northeast of Bessemer. A great deal of float greisen carrying cassiterite has been found on a small hill about 100 yards from the house and a number of shafts and open cuts have been sunk on small masses of greisen that were observed out-cropping on the surface. One of these, which was 2 to 3 feet wide, had a strike of nearly N. 80° W. and is cutting at almost right angles the trend of the gneiss. This vein carried considerable tin ore, and, judging from a test made by panning down a sample taken from the vein in the shaft, it would carry in the neighborhood of 5 per cent. of cassiterite. This vein varies very greatly in the percentage of cassiterite that it contains, and a cross-cut made about 70 feet west of the shaft showed only a little cassiterite, and another cut 70 feet still further to the west did not show any cassiterite at all, and the vein contained considerable altered feldspar. The shaft is now partially filled with *debris,* but it is reported that it continued in ore to the bottom. As far as it could be examined, it still showed good tin ore. There is an area on the slopes of this hill and along the branch, making an area of about 200 by 300 feet in which cassiterite has been found, and would represent the alluvial deposits that are known at the present time and which will probably pay to hydraulic. During the winter of 1903 and 1904 work was again begun on these deposits and the saprolitic rock and alluvium were being washed and concentrated in the stream

at the foot of the hill. Throughout nearly all the tin belt to the northeast of Kings Mountain the scarcity of water is a serious drawback.

OTHER TIN LOCALITIES IN THE UNITED STATES.

Cassiterite has been found at a number of localities throughout the United States, but usually in only small quantities and often simply as isolated crystals.

Maine.—In Maine* cassiterite has been found very sparingly at Paris, Hebron, Winslow and Stoneham. At the two former localities it has been found well crystallized and associated with the beautiful tourmalines for which these localities are noted. They occur in pegmatitic dikes which have been highly mineralized. At Winslow, Maine, cassiterite has been found associated with quartz, mica and fluorspar in limestone. They occur in thin seams one to two inches in width, sometimes following, at others cutting across the stratification.

New Hampshire.—In New Hampshire† cassiterite has been found in some quantity in the town of Jackson and at Lime, in both places being associated with iron, copper and other sulphides.

Massachusetts.—At Chesterfield and Goshen, Massachusetts,‡ cassiterite has been found associated with tourmaline in pegmatitic dikes similarly as at the Maine localities, but it is not as well crystallized.

Virginia.—The occurrence of tin in Virginia was described by Mr. Arthur Winslow§ in 1885, and later by Mr. Titus Ulke¶ in 1893. This tin area extends along the eastern edge of Rockbridge county in the line of the Blue Ridge Mountains from a few miles north of the James River Gap to about the north line of the county. Cassiterite has been found at a number of places in this area, but the greatest amount of ore was found along the upper waters of Irish creek in the northeastern corner of the county. There is one property that has been developed to some extent, and this is known as the Cash mine. The greisen veins in which the tin occurs traverse the granite in all directions and are dipping at very steep angles.

*Trans. Am. Inst. Min., Eng., Vol. I, 1871-73, p. 373.
†Dana Mineralogy, 6th Edition, 1892, p. 235.
‡Dana Mineralogy, 6th Edtion, 1892, p. 235.
§Eng. and Min. Jour., Nov. 7, 1885.
¶U. S. Geol. Survey, Min. Res., 1893, p. 180.

The width of these veins is usually from 8 to 12 inches, though some were observed that were several feet in thickness. The cassiterite is occasionally concentrated into seams from 1 to 2 inches wide and is associated with pyrite and arsenopyrite, the rest of the gangue of the veins being composed of quartz and mica. The principal work was done here about twenty years ago, and a concentrating mill was erected on the property and about 290 tons of rock were tested. It is reported that about 2,400 pounds of tin concentrates were shipped to Boston, but that they only averaged about 43 per cent. of metallic tin, due to the concentrates being contaminated with arsenopyrite and ilmenite. There was not sufficient work done on the property to definitely determine whether or not there existed a commercial deposit of cassiterite.

Alabama.—Tin has been found in Coosa county, Alabama,* near Brockford, associated with tourmaline, biotite and tantalite.

South Dakota.—The South Dakota† tin deposits have attracted the greatest attention, and a great deal of work has been done on the deposits in that State in an attempt to open commercial bodies of tin ore. The deposits lie to the west and south of Custer and throughout what is known as the Nigger Hill District, which is west of Deadwood, extending down into Wyoming. The principal deposits that have been opened up are known as the Etta and Ingersoll mines about 6 miles east of Harney Peak and 20 miles from Rapid City. The occurrence of the tin at both of these mines is very similar, and a description of one would fit closely that of the other. At the Etta mine there is a granitic knob in the form of a conical hill, which is cutting through mica and garnetiferous slates, and is about 250 feet high by 200 feet in its longest diameter and 100 to 150 feet in its transverse diameter, as measured across the outcrop. This mass of granitic rock has a somewhat concentric structure, the outer portions next to the slates being composed of a band or belt of dark-colored mica; then a zone of very large spodumene crystals with albite, feldspar and irregular bunches of crystals of mica and albite. Next is the greisen rock, which has cassiterite disseminated through it in small grains and imperfectly formed crystals. The centers of these granitic knobs are a mixture of quartz and feldspar.

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*Dana's Mineralogy, 6th Edition, 1892, p. 235.

†W. P. Blake, Trans. Am. Inst. Min. Eng., Vol. XIII, 1885, p. 691.

Texas.—Cassiterite has been found in Texas* on the east flank of the Franklin Mountains, the southern extension of the Oregon or San Andreas Range, about 10 miles north of El Paso. These deposits were discovered in 1899 and had been prospected to a depth of about 50 feet. The ore occurs in well-defined veins, which have a strike approximately east and west, which is nearly at right angles to the direction of the range and are dipping toward the north at very steep angles. There have been three veins discovered here, which have been exposed by pits and open cuts for several hundred feet along the strike. The veins occur in the granite and are considered by Mr. W. H. Weed† to be the result of deep-seated agencies and that further exploration will develop well-defined tin veins.

California.—The California‡ tin deposits have also attracted more or less attention, and those in Riverside county in the Temiscal District have been producers to the extent of probably about 40,000 pounds of metallic tin. The principal mine in the district was the Cajalco on the San Jacinto estate. The tin deposits lie nearly in the center of a rudely semicircular area of granite about two miles in diameter, which is cutting the sedimentary rocks, quartzite, mica schist and conglomerate. In some instances porphyry is bordering the granite. Towards the outer edges of this granitic boss are numerous dikes of very fine-grained granite, consisting almost entirely of quartz and orthoclase feldspar in interlocking grains. This semicircular area of granite and portions of the adjoining porphyry have been fissured in a general north-east and south-west direction, while almost innumerable lines have been subsequently filled with black vein matter. These veins are usually small, varying from a quarter to a few inches in thickness, but in one case, that of the Cajalco vein, it reaches an enormous width. The vein material of this main vein and the smaller ones consists for the most part of tourmaline and quartz. The larger veins are very irregular and sometimes appear to be but bunches of vein matter in the granite. A few hundred feet northeast of this wide portion of the vein it has narrowed down to 6 or 8 feet. But little development work has been done on this property to prove the existence of large bodies of tin ore. Most of

* Bull. U. S. Geolog. Survey, No. 213, p. 99.
† Ibid.
‡ Am. Jour. of Sci., Vol. IV, 1897, p. 39.

the money expended was on top of the ground in buildings, roads, etc. It is not at all improbable but that conservative development work would show the existence of a sufficient quantity of ore to make profitable mining.

Another locality in California that is attracting some attention is on the west slope of the Santa Anna Mountains in Trabuso Canyon, Orange county. This property is now being developed, but it has not been definitely determined as to the quantity of tin that it contains or whether it is possible to make it a producer of this metal.

Alaska.—Perhaps the most promising tin region in the territory of the United States, outside of the Carolinas tin belt, is that in Alaska,* near Port Clarence, in the York region. Cassiterite has been found as stream tin at a number of localities in this region, principally on Buhner creek, about 10 miles east of Cape Prince of Wales, and on the Anikovik river, about half a mile below the mouth of Buhner creek. Tin has also been found in place by Mr. Arthur J. Collier, of the United States Geological Survey. Its occurrence is similar to that of cassiterite from other localities, and it is associated with fluorite, tourmaline and wolframite. Although undeveloped, the indications are such that it makes a promising locality for further investigation as to its commercial possibilities. Stream tin has also been found at Copper river, about 125 miles northeast of Valdez, by Mr. A. W. Tibbitt of that town.

Other States.—Other localities in the United States where stream tin has been found are in Crook county, Wyoming; near Dillon, Montana; and at Jordan creek, near Booneville, Idaho; but at none of these has there been any indication of the mineral occurring in commercial quantity.

It will be seen from the above that thus far no profitable tin mining has been accomplished in the United States and that all the deposits are still in the prospective stage. Considering, however, the value of tin ore, the quantity of the metal that is used in the United States and its limited occurrence in other parts of the world, the Carolina tin deposits are well worthy of a thorough, systematic investigation as to their commercial value. In some instances it will be found that

* U. S. Geolog. Survey, Mineral Resources, 1900, p. 267.

a considerable portion of the cost of this development work will be paid for by the value of the cassiterite obtained.

FOREIGN TIN LOCALITIES.

Malay Peninsula.—The world's chief source of supply of tin is from the deposits on the Malay Peninsula,* which extend from the extreme southern end of the Peninsula northwestward for a distance of about 350 miles to the border of the Siamese possessions. Throughout this entire distance tin ore is found in more or less quantity, and it has also been reported to occur still further north into the possessions of Siam; but up to the present time these latter deposits have been explored but little and nothing definite is known regarding their extent or commercial possibilities.

Extending almost the entire length of the Malay Peninsula is a long, high mountain range, forming the backbone of the Peninsula, and it is only on the western slopes of this range that the tin ore has been found. Although tin has been found over such an extensive area in the Federated Malay States, it is only from a few districts that it has been proved to be in commercial quantity. The State producing the largest quantity of tin is Perak, from which is obtained over one-half of the total quantity of tin obtained on the Peninsula, which in turn produces over half of the world's supply of this metal. The principal mining district of Perak is known as the Kinta, and this is the largest and most celebrated tin mining district in the world. Selangor is the second largest tin-producing State on the Malay Peninsula, but its production is far below that of Perak. Other States from which small amounts are mined are Pahang, Negri Sembilan and Johor. This latter State is at the extreme end of the Peninsula.

The tin ore is obtained almost entirely from the alluvial deposits, although deposits of tin have been discovered in granite and also in limestone. Up to the present time, however, these latter deposits have not proved to be profitable mining. The cassiterite is found in these alluvial deposits, sometimes scattered through it from top to bottom, but in most cases, however, there is an overburden of soil from 1 to 40 feet, which is almost entirely barren of any tin ore. The

* Jour. Geol., Vol. XI, No. 2, 1903, p. 135.

most profitable alluvial deposits occur at the foot of the mountains. Higher up the mountain slopes it has been found richer, but on account of the very small area over which these extend, they do not make profitable mining like the more extensive areas lower down. The tin in the alluvium has undoubtedly been derived from the neighboring rocks, granite and limestone. It occurs in the granite in the form of small pockets or veins from which stringers are often running out, intersecting each other in various directions, forming often a network of tin-bearing seams. The principal minerals associated with the cassiterite are quartz, tourmaline, fluorite and pyrite. Where it is found in the limestone it is usually along the zone of fracturing, either as an impregnation or as lenses, or irregular pockets. Seams carrying tin ore are often found following the cracks in the rock and running out into it for some distance. The minerals associated with the cassiterite found in the limestone are for the most part sulphides, there being large quantities of pyrite and arsenopyrite with smaller amounts of the copper minerals, chalcopyrite and bornite.

The general method of working these deposits is by open cuts or large pits, but in those cases where the overburden is too deep, shafts are sunk until the tin-bearing strata are encountered. On account of the difficulty of taking care of the water, the pits and cuts that are made by Chinese are usually shallow, seldom averaging over forty feet deep. After the tin-bearing alluvium has been brought to the surface, which has been accomplished by means of small baskets hung on both ends of a stick and suspended on a man's back, it is dumped into long wooden troughs, in which there is a stream of running water. If there is much clay in the alluvium, the material is stirred with shovels and hoes to separate the tin ore. The materials are carried by the water from the troughs into sluice boxes, where the tin ore and other heavy minerals sink to the bottom, while the lighter materials are carried away by the stream. These sluices vary from a few feet to several hundred feet in length, according to existing conditions, and are made of wood. Occasionally cuts are made in the sandy clay of the region, which are used in place of the wooden troughs. After this operation has been carried on for several hours, the flow of water is stopped and the material that has been concen-

trated on the bottom of the sluice boxes is still further concentrated by panning in flat wooden bowls, which in shape are similar to the ordinary iron gold-pan. The concentrates are still further purified by picking out by hand the magnetite and other heavy minerals. The final product contains from 69 to 73 per cent. metallic tin.

Formerly all the tin ore was smelted at local works in the various districts, but now it is nearly all treated at the smelters of the Straits Company, located at Singapore. The agents of this company are in constant touch with all the producers of tin so that they practically control the output of tin ore from the various mining districts. On account of a high export tax which has been placed by the Government on tin ore, it is impracticable to attempt to smelt these ores elsewhere. Before this export tax was imposed, a company had been organized in the United States whose object was to erect a smelter and to treat tin ores. Their source of supply was to be mainly from the Malay Peninsula. On account, however, of this export tax the project has failed.

Banka and Billiton.—On the Islands of Banka and Billiton, which are 200 to 300 miles southeast of the southern extremity of the Malay Peninsula, is located the second largest tin mining district of the world. These islands are owned by the Dutch, and the Banka mines are worked by the Government, while those on Billiton are operated by an independent company. The production from Banka is over three times that from Billiton, and is probably due to the Government having supervision of the mines. The combined Banka and Billiton mines produce a little over one-fifth of the world's production of tin. The occurrence of the tin on these islands is very similar to that on the Malay Peninsula.

Sumatra.—On the Island of Sumatra, in the District of Siak, tin has been found, but on account of the inaccessibility of the district and of the internal troubles between the natives and the Dutch Government, these deposits have not been thoroughly explored.

Bolivia.—The Bolivian deposits* are the third largest producers of tin, their output being about one-tenth of the world's production. Tin has been found over a wide area along the eastern edge of the Bolivian table-land, which forms the extreme western part of Bolivia, for a distance of about 300 miles in a north and south direction,

* Min. Ind., 1892, p. 543.

across the Departments of La Paz, Oruro and Potosi. There are a number of localities in each of these Departments where tin occurs in paying quantities and is being mined at the present time. The principal deposits which are known are Huayna, Potosi, Totoral, Berenguela, Tres Cruces, Sayaquiri and Quisma-Crur in the Department of La Paz; Huanuni, Colquiri, Negro Pabellon, Antigura and Morococala in the Department of Oruro; and Llallagua, Apacheta, Chorolque and Tazna in the Department of Potosi. These deposits are at an altitude of from 13,000 to 15,000 feet above sea-level, and some of them, as those in the great Chorolque Mountain, are 17,000 feet high. The tin ore occurs in veins which are dipping at angles from 50° to 70° and vary in width from a mere seam to 25 or more feet in width. These veins are found cutting through the metamorphic shales and also in the adjacent igneous rocks. The tin minerals usually occur in streaks in the veins, the gangue being made up largely of silica, with some feldspar, the latter being more or less kaolinized. As a rule, however, the gangue matter is solid.

It has been estimated that the ores in Huanuni and Avicaya will average from 10 to 12 per cent. metallic tin. The ores are crushed either by stamp mills or by crushers and rolls and then sieved. The pulverized material is then passed through hydraulic separators, slimes or lighter material being carried off at the top into settling tanks, after which it is treated in round buddles and on Wilfley tables. The coarser material from the hydraulic separators is classified in trommels and concentrated in automatic jigs. The concentrates are further treated by washing in sieves, after which they are dried and sacked for export. Some of these deposits have been worked to a depth of 300 to 400 feet, but it has not been proved definitely as yet to what extent they will prove profitable.

England.—The Cornish tin mines of England* are perhaps the most widely known of any of the deposits of this metal, and were undoubtedly the first to produce tin. For over 2,000 years these deposits have been furnishing England with tin, and are still producing at the rate of 4,000 tons or more per year. The alluvial deposits were formerly worked very extensively, but at the present time it is from the under-ground mines that the tin ore is

*Trans. Min. Ass. and Inst. of Cornwall, Vol. III, Parts 1 and 2; and Mineral Industry, Vol. I, 1892, p. 439.

obtained. The veins occur principally in granite overlain with a slate, and are dipping at high angles to nearly vertical. Cutting both these rocks are a series of quartz-porphyry dikes, while the veins carrying the tin traverse all three of these rocks, thus showing that they were formed at a later period than any of the others. Where these veins are found cutting the slates they are not apt to carry very much tin, but more copper; while on the other hand, as they penetrate into the granite the copper gives out and they become rich in tin. While there is a main vein or leader which can be constantly followed with a permanent dip and strike, there is constantly branching out from this stringers and seams which penetrate into the adjoining country rock, and sometimes are so large that they exceed in extent the main lode. Then again, portions of the country rock itself are impregnated with the tin ore, so that there is a gradation from the ore to the barren country rock. This is true of the veins in the slate and also in the granite. Occasionally a lead will be opened up that has a slate for one wall and a granite for the other. These are the deepest workings of any in the history of tin mining, and they are now down over 2,000 feet below sea-level. The rock as it is obtained from the mine is usually crushed in stamp mills, the larger lumps being broken by hammers. It is crushed in these mills fine enough to pass through a 40-mesh screen, from which it is carried by water to the concentrating room, where various appliances are utilized to effect this concentration.

Australia.—The production of tin from Australia is now beginning to exceed that from England, and these deposits are taking a prominent place in the world's production of this metal. It is mined in New South Wales and Queensland and on the Island of Tasmania. It has also been found in Victoria; but its production in this latter province is very small. In Western Australia tin was discovered in the latter part of 1888 near Bridgetown, and the alluvial deposits have been worked on a small scale; but until a larger water supply can be secured they cannot be developed as fully as the percentage of tin warrants. The Government has recently erected a tin-dressing plant as an aid to the development of the tin mining industry in that section.

In New South Wales the principal mining sections are at Emma-

ville and Tingha, in the northern part of the colony. At Tingha, Hardinge county, the alluvial deposits are worked by dredging, and a considerable area of rich ground has been shown to exist in the beds of Coke's creek and tributaries. The largest amount of work has been done in the vicinity of Emmaville, Clive county. Other localities in New South Wales where tin deposits are being developed are at Silent Grove in the Deep Water District and at a number of places in the Broken Hill District.

The tin deposits of Queensland are in the Herberton District, which comprises an area of about 750 square miles, and this district produces about one-half the tin obtained in Australia. Irvinebank is the principal center of this mining district, and in its vicinity are two of the largest producers, the Vulcan and Tornado mines. Other districts in Queensland which are producing small amounts of tin are Cookestown, Kangaroo Hills, Palmira and Stanthorpe. Nearly all the tin that is mined in the Herberton District is from veins, while that from the other districts is obtained from alluvial deposits.

Tasmania.—The tin deposits of Tasmania* were discovered at an early period in the history of this colony, but not until 1872 were any profitable deposits found. In that year was discovered the great Mt. Naschoff, which has continued to be the largest producer in Tasmania. While at first mining was confined entirely to the alluvial deposits, now the greater part of the tin is obtained from deep mining on the veins.

Mexico.—In Mexico there are numerous localities where tin has been found, and it offers a promising field for prospecting for this metal. The principal deposits are at Potrillos in the State of Durango; at Sain Alto in Zacatecas; in the Santa Mario del Rio District of Sain Luis Potosi. This belt, which extends in a northwest direction, produces each year a few hundred tons of tin, all of which is used in Mexico. Both veins and alluvial deposits are worked; but at the present time the most of the production is from the latter deposits.

Other Localities.—Tin has also been found and worked in certain parts of China, but little is known regarding its occurrence or the amount of production. There is also a small amount produced in

*Min. Ind., 1892, p. 451.

Japan and Burmah. Tin deposits have been reported from Peru and Chili in South America, but as yet have not become producers of this metal. In Europe there are small amounts of tin that have been reported from Spain, Portugal, Germany and Austria, but the combined production from these countries is very small as compared with the world's production.

There has been a small amount of tin ore produced in Swazieland, South Africa. The deposits from which the ore was obtained are on the eastern slope of the Drakensberg Mountain, about 15 miles from the Transvaal border.

ORIGIN OF THE TIN ORE.

It is the authors' idea regarding the origin of the tin ore found in the Carolina belt, that it is due partly to the direct separation or recrystallization of the cassiterite from the molten pegmatite magma, but it is also due to a fumarole action, resulting from the escaping vapors during the crystallization of the molten magma of pegmatite intruded into the schists and gneisses in the form of dikes, which in turn had thrown off apophyses and lens-shaped masses or "augen," that have been subjected to the same reactions as the main mass of pegmatite.

HISTORICAL.

In discussing this method of origin of the tin ore, consideration has been given to the theories advanced for the origin of other occurrences throughout the world, and there are given first short statements regarding these.

Regarding the origin of the tin in the granites in the Kinta District of the Malay Peninsula, Mr. R. A. F. Penrose* says:

"In the granite, the occurrence of the cassiterite in veins, stringers, networks, etc., along lines of fracturing, are strong evidences of aqueous deposition of the ore; while the occurrence as an impregnation in the rock where no marked fissuring occurs, may be due either to segregation during a more or less molten condition of the rock or to aqueous concentration in a solidified rock. It is possible that the tin was originally a disseminated constituent of the granitic rocks; and in places its concentration may have been due to segregation from a molten mass, but there can be no doubt that some of the concentra-

* Jour. of Geol., Vol. XI, No. 2, 1904, p. 149.

tion, as at present seen, was due to water action after the solidification of the rock."

Mr. W. H. Weed,* in discussing the El Paso, Texas, deposits, says:

"The veins exhibit the usual characters of the European tin veins, notably those of Cornwall, England, their clearly-defined fissures showing a central core of lead or coarse quartz, sometimes containing tin ore, and flanked on either side by altered rock, in which the tin ore replaces the feldspar of the granite. Where this metasomatic replacement is complete, the ore shows a mixture of cassiterite with or without wolframite and quartz. Where the replacement is only partial, the greisen ore fades off into the unaltered granite. A cross-section of the vein shows, therefore, the same phenomena seen in Cornwall. The central mass of quartz corresponds to the 'leader' of the Cornish veins. It is composed of massive, coarsely crystalline quartz, sometimes showing comb structure, and it is clearly the result of the filling of the open fissure by quartz. The adjacent ore-bearing material is a replacement deposit in which the mineral solutions have substituted for the feldspar of the granite by metasomatic action; in other words, the main mass of the ore occurs alongside of a quartz vein, and is due to the alteration of the granite forming the walls of the fissure. In general, the ore passes into the granite by insensible transition, and there are no distinct walls."

Dr. H. W. Fairbanks,* in discussing the large Cajalco vein of California, says:

"The deposits have evidently been formed in fissures through a gradual replacement of the granite walls. Judging from an examination of the seam-like veins, the silicates appear to have been attacked easier and removed first. In places the larger veins seem to blend into the granite, and it was at first thought that some of the quartz might be a remnant of the granite, as it is rarely, if ever, segregated in bunches. A microscopic examination showed that this view was undoubtedly false, as the grains interlock in a different manner from those in the granite, and in addition contained fluid and liquid inclusions. The relative proportions of quartz and tourmaline in the Cajalco vein are so constant that it represents a uniform appearance. * * * The bunches in these veins, and especially

*Bull. U. S. Geol. Survey, No. 213, 1902, p. 100.
*Am. J. Sci., Vol. IV, 1897, p. 41.

the enormous one forming Cajalco hill, could have been formed in no other way than by replacement, although it is difficult to conceive of its having taken place on such a large scale."

The origin of the cassiterite occurring in the small veins in rhyolite that are found at Sain Alto, Mexico, is referred to by the Geological Institute of Mexico,* which makes the following statement:

"The veins appear to have been formed from lines of fracture produced by contraction due to cooling and to have been filled by direct emanation. The associated minerals are hematite, topaz, and in some places durangite—that is to say, two minerals which contain fluorine, thus bearing evidence of the identity of the agent employed by nature in bringing tin to the surface in the same state of combination and at different and widely separated geological periods, and always, be it remembered, in the most acid rocks of the two series of eruptions; in the ancient series tin appears in granite containing white mica, while in Mexico, where the most impure emanations of tin have taken place, it appears in rhyolite of the upper Tertiary."

Dr. Albert R. Ledoux,† in discussing the deposits of tin in North Carolina, says:

"Having secured permission to investigate the properties, we examined them by open cuts and shafts in perhaps half a dozen places for an extent of, occasionally at least, 2 miles north and south, and I have also visited openings which others have made since we began operations, at a distance of 6 or 7 miles from the village. We also put down a number of holes with a diamond drill for the purpose of determining the character at considerable depth. The drill, I may say here, shows these greisens apparently to be large, irregularly bedded masses, their vertical extent being in no way determinable by their appearance on the surface. They are unquestionably bedded veins, although occasionally, when cut by trap dikes or from other local causes, taking on the appearance of true fissure veins. Our deepest hole has shown layers of schist and greisen, greisen and slate, slate and greisen, etc., indefinitely."

Professor William Blake,‡ commenting on the origin of the tin ore found in the Black Hills, says:

*Bulletins Nos. 4, 5, 6, 1897, pp. 234, 235.
†Eng. and Min. Jour., Vol. 48, 1889, p. 521.
‡Trans. Am. Inst. Min. Eng., Vol. XIII, 1885, p. 695.

"In the numerous tin veins and tin-ore-bearing granitic dikes of the Black Hills tin region, the phenomena of occurrence and association indicate that all of the minerals of the dikes—the quartz, feldspar, spodumene, mica, beryl, columbite, tantalite, phosphates, and other associates of the cassiterite, were contemporaneous in origin. The tin-stone is apparently as much a part of the mass as the mica or quartz. It was, to all appearance, present when the whole mass assumed its crystallization. All the constituents of the dike appear to have crystallized from a semi-fluid or pasty magma, in which the elements were free to arrange themselves from one side of the dike to the other and to crystallize out slowly. This is indicated in several ways, but strikingly by the gigantic crystals of spodumene stretching across the mass at the Etta, in straight lines, for 20 to 40 feet, in the midst of quartz, feldspar and tin ore."

The occurrence of the South Dakota tin ores is unlike that which would be expected to be seen in narrow fissures that have been filled gradually by solutions depositing layer after layer on each side of the fissure until the same becomes filled up. There is also a decided lack of any signs of infiltration or of alteration or of replacement of the minerals by tin-stone, and thus this has the appearance of being one of the original constituents of the granite.

Mr. J. H. Collins,* in commenting on the Cornwall cassiterite, states that it occurs as

"(1) pebbles, rough masses or grains (stream tin); * * * (2) filling of definite fissures in granite, slate and porphyry; * * (3) the filling of minor joints and shrinkage cracks (the latter, when numerous, form stock works); * * * (4) cementing material for conglomerates and breccias in fissures; * * * (5) as a constituent of ancient breccias occupying the fissures; * * * (6) as a minor constituent of granite, porphyry and in tourmaline schist; * * * (7) as a pseudomorphous replacement of feldspar, quartz, etc; * * * (8) as pseudomorphous replacement of organic structure."

Professor J. F. Kemp,† in speaking of the deposits of tin ore in a general way, says that they have been especially developed along the contacts of granite intrusions.

*Min. Mag. London, Vol. IV, 1880.

†Ore Deposits of the United States, 1900, p. 69.

"Granite, as is well known, is the most potent of all rocks in bringing about contact metamorphism. It seems to be especially rich in mineralizers, and as its great, intruded, batholitic masses slowly crystallize, they emit boracic, hydrofluoric and other vapors in exceptional volume. Wall rocks are greatly corroded and charged with tourmaline, fluorite, axinite, topaz, fluoric micas and cassiterite. Pegmatite dikes or veins are sent off as apophyses, and are charged with the same association of minerals. If the walls themselves are granitic in composition, the feldspar becomes greatly corroded, and may be replaced by quartz and fluoric micas with more or less cassiterite. Pegmatites consisting essentially of the same minerals are also produced, and both varieties are called greisen, and are recognized as the characteristic gangue of tin ores the world over."

Again, on page 442, Professor Kemp says:

"Cassiterite occurs in small stringers and veins on the borders of granite knobs or bosses, either in the granite itself or in the adjacent rocks, in such relations that it is doubtless the result of fumarole action, consequent on the intrusion of the granite."

Cassiterite was first made synthetically by Darubree* by decomposing the vapors of the bichloride of tin ($SnCl_2$) with steam at high temperature, the products obtained being small crystals, identical in form with the natural cassiterite. Henri Sainte-Clair Deville and Caron† produced artificial cassiterite or tin oxide (SnO_2) by a similar method, but using vapors of the fluoride of tin instead of the chloride. These crystals of tin oxide which were obtained were also identical in form with the natural product.

EVIDENCE BEARING ON ORIGIN.

This synthetical production of tin oxide, identical in composition and crystallization with natural cassiterite, offers a clue to the origin of some of the deposits of this mineral, and is strong evidence that considerable of the tin oxide found in nature has been produced by the action of vapors of tin chloride or tin fluoride on the masses and dikes of pegmatite veins by the metasomatic replacement of the feldspar with tin oxide. This has more probably been accomplished by the action of the fluoride; for of the associated minerals that are found

*Synthese des Mineraux et e des Roches, by Fouque et Michellevy, 1883.
†Loc. cit.

with the cassiterite (tin ore), those that contain fluorine are common; while seldom, if ever, are any of the chlorides or minerals containing any appreciable amount of chlorine found. The hot steam vapors which would be present, especially along the contact of these pegmatitic masses and dikes, with the other country rock would react with the stannic fluoride (SnF_4) in the formation of the tin oxide (SnO_2), setting free probably hydrofluoric acid (HF), which would readily attack any of the silicates, replacing them, to some extent at least, with the tin oxide and forming the silicates containing fluorine and also producing some fluorite, calcium fluoride. This would also account to some extent for the honey-comb appearance that is often observed in the quartz carrying tin.

As has already been stated, there are three occurrences of the cassiterite in the Carolina belt: (1) As lenses and veins in the schist whose strike and dip correspond approximately to that of the schist; (2) the more clearly defined veins, which are cutting across the lamination of the schist or gneiss; and (3) veins occurring in gneiss, as those at the Ross mine. All of these veins are considered as belonging to the same pegmatitic formation, and to have been formed at the same time. There is one large and almost continuous dike which has been observed, which can be traced almost continuously from a short distance above Kings Mountain nearly to Grover, North Carolina, a distance of 7 miles, varying in width from 25 feet to nearly 200 yards. These pegmatitic dikes, which have for the most part resisted alteration and erosion better than the surrounding schists, outcrop prominently and can thus be readily traced across country. This pegmatitic material occurs as a series of lenticular-shaped masses breaking through the schist approximately paralleling the main dike of pegmatite. These masses of pegmatite are separated from each other by schist and often pinch out along the strike. Before, however, they have given out entirely another lens is apt to be encountered.

This occurrence is represented in Fig. 6, which shows the irregular mass of the main pegmatitic dike parallel to which are what seem to be a series of the lenses of pegmatite, which are connected with each other by very narrow seams of pegmatitic material. As this main mass of pegmatite was intruded into the schist the apophyses, which

were thrown off from the main mass and forced their way up between the laminations of the schist, would have a tendency not only to form a series of lenses in a vertical direction, but also horizontally, and this latter series would, upon erosion, be exposed on the surface similarly as represented in Fig. 6.

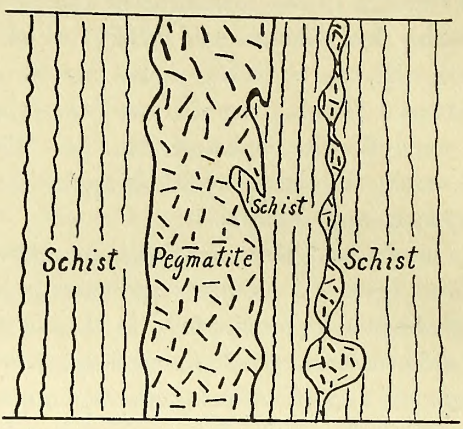

FIG. 6.—A HORIZONTAL CROSS-SECTION OF A MASS OF PEGMATITE INTRUDED INTO SCHIST.

In general, where pegmatitic dikes are cutting through schists, following closely the strike of the laminations of the schist, they are apt to be irregular and to throw off numerous apophyses, which ramify between the laminations of the schist, giving the pegmatite a very irregular and peculiar outline. In Fig. 7 (p. 47) is an ideal vertical cross-section of such a mass of pegmatite intruded into the schistose rock where the strike of the dike is approximately that of the schist. Such a mass of pegmatite, upon erosion, would appear on the surface to be made up of a series of separate masses of pegmatite, while in reality they would all be parts of the same dike. Such an appearance is illustrated in Fig. 8 (p. 47), which shows ideally a horizontal cross-section of the same mass of pegmatite which is illustrated in Fig. 7, if this had been eroded to line AA. The apophyses 1, 2 and 3 of Fig. 7 would appear on the surface as distinct and separate masses of pegmatite, 1, 2 and 3 of Fig. 8, and which apparently have no connection whatever with the main mass of pegmatite, 4 of Fig. 8 being separated from it by the schist.

Such occurences of pegmatite showing similar irregularities in structure have been observed in the northern part of North Carolina

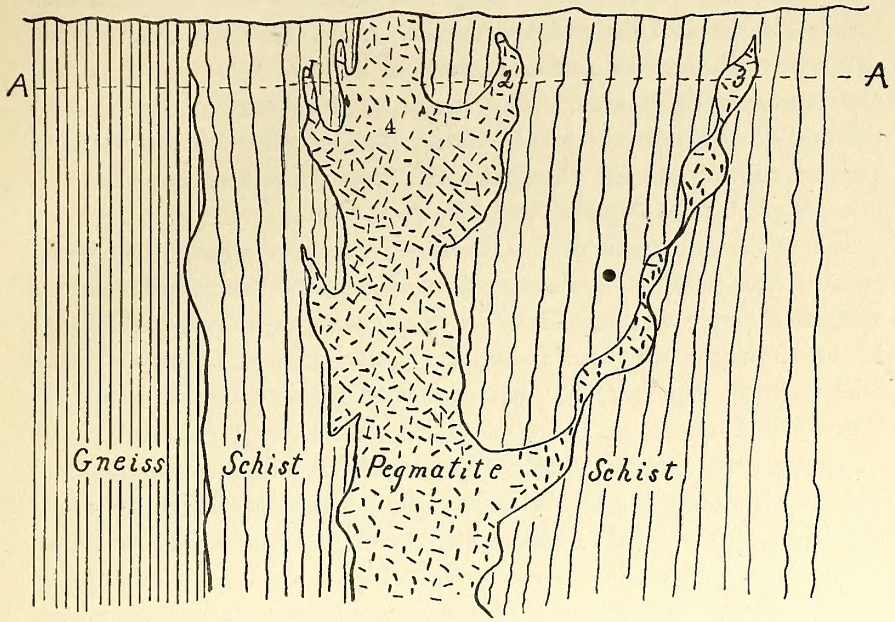

FIG. 7.—IDEAL VERTICAL CROSS-SECTION OF AN IRREGULAR MASS OF PEGMATITE INTRUDED INTO SCHIST.

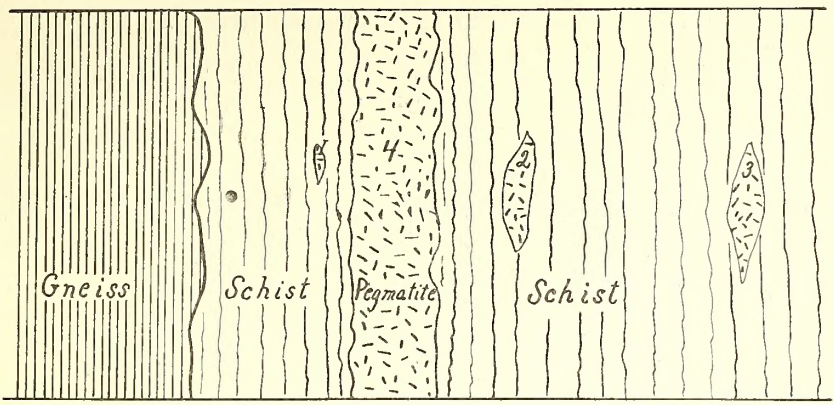

FIG. 8.—IDEAL HORIZONTAL CROSS-SECTION OF A MASS OF PEGMATITE IN SCHIST.

in Mitchell and Yancey counties, where these dikes contain commercial quantities of mica, and mining is being carried on for this mineral. At the Burton and White mica mine, Mitchell County, an occurrence of pegmatite was observed of which Fig. 6 would be an almost exact reproduction. This is also true as the pegmatitic formation is followed northeastward, all the dikes or veins being of rather narrow width until the Ramseur Mill property is reached, where a mass of pegmatite was observed 200 feet wide.

Where the pegmatitic dikes are cutting across the strata of the sedimentary rocks they are more even in width, and are usually occurring as a single distinct dike. In many cases these cross dikes are in the vicinity of the amphibolite dikes, and are approximately parallel to them, and they may have followed a fracture formed at the time of the intrusion of the amphibolite. More rarely the pegmatitic dikes are cutting across not only the schist but also the amphibolite. The fluorine minerals that have been found associated directly with the tin ore are tourmaline and a fluorine mica. There has also been a considerable tourmalinization of the schist to the east of these pegmatitic dikes. Where the wall rocks do not contain any feldspar they are not as apt to be affected by the action of the vapors as where the feldspar forms a prominent constituent of the rock.

After the intrusion of these pegmatitic dikes, and as they began to crystallize, they were giving off boracic, hydrofluoric and other vapors, which corroded the wall rocks, reacting on the minerals present in them, especially if they happen to be feldspars, and charging these wall rocks with tourmaline, fluoric micas, etc.

There has been thrown out from the main mass or dike of pegmatite apophyses of the same material, which are also charged with these vapors and gases, which react in the same way as in the larger mass. Thus, where there is a large mass of pegmatite, the mineralization is along the borders of this and in the walls of the adjacent rocks and in the apophyses and lens-shaped masses that have been thrown off; while there is but little change within the main mass of the pegmatite itself. In this way is formed the tourmaline that is observed so abundantly in some of the rocks adjoining the pegmatite. There was no occurrence observed where the rocks were impregnated so abundantly that it could be called a tourmalinization of the wall rock.

The tourmalinization that has taken place in the Carolina field has all been east of the tin belt.

Where the pegmatites are cutting gneisses containing considerable feldspar, the reactions of the hydrofluoric and other acids have been spent in some degree on this feldspar as well as on the feldspar of the pegmatitic dike itself. Thus, in these veins, as would be expected, there is more or less feldspar associated with the tin. Where these dikes have cut through schists, the original feldspar of the dike would be apt to be pretty thoroughly replaced by other minerals, as tourmaline, cassiterite, etc.; as this mineral would be acted upon more readily than any of the others. Thus, in the tin veins cutting the schists, the vein material consists almost entirely of quartz, mica and tin, the two latter minerals representing, at least in part, replacement products of the feldspar.

There was not observed in any of the veins examined any indication of a ribbon structure or any other structure that resembled the filling of narrow fissures by depositions from solutions from the sides of the fissure.

The cassiterite occurs more or less crystallized in a matrix of quartz and mica, with occasionally feldspar. Where the dikes are very small it is rather evenly distributed throughout the vein, but where it occurs in the broad dikes or lenses it is more generally concentrated toward one wall or the other.

Many of the facts stated above would apply to the theory that the tin oxide was an original constituent of the igneous magma instead of being in the form of the fluoride; and it may be that it has been partially formed in this manner, but still it seems as though the argument was in favor of the fumarole action, resulting from the escaping vapors during the crystallization of the molten pegmatite magma. The absence of feldspar in the dikes which are cutting the schist and its presence in those cutting the gneiss, when all the dikes are of the same geological formation, are in favor of the latter view.

METHOD OF CONCENTRATING THE TIN ORE.

ALLUVIAL DEPOSITS.

At the present time the only tin ore that is being mined in the Carolina belt is that which can be treated hydraulically, and consists of gravels, soils and saprolitic veins carrying tin. This material is washed similarly as in placer gold mining by first throwing the gravels, etc., on a perforated plate to eliminate boulders, twigs, etc., and then by running the material through sluice boxes. It is not necessary as a rule to use more than one or at most two boxes to save all the tin. These sluice boxes are about 8 feet long by 20 inches wide and 20 inches deep. There are two men required to operate each of these boxes, one to charge the gravel on to the perforated plate, which is fastened on to the upper end of the box, and the other to work the material in the sluice boxes up and down so as to permit the lighter materials to be carried off by the water. These boxes are usually cleaned up at the end of each day and the concentrates dried. In some instances a very pure tin concentrate has been obtained that did not require any further refinement. In the South Carolina portion of the belt concentrates are apt to be diluted with monazite and garnet, while in the North Carolina portion of the belt the principal accessory mineral is generally ilmenite.

It may be found advantageous, however, to run the concentrates, after they have been dried, over a magnetic separator in order to remove any ilmenite or magnetite that may happen to be present, and also by this same process any wolframite, garnet, or even monazite, that is present can be removed. The Wetherill magnetic separator could be used very advantageously for this purpose.

Thus far there has not been observed in the concentrates any sulphides or arsenides in sufficient quantity to detract from the value of these concentrates, and which, if present in any amount, would make it necessary to roast the ore to eliminate the sulphur and arsenic. If these were present, the magnetic separator could be so adjusted as to undoubtedly remove at least the iron sulphides.

Sluicing is being carried on at the present time at the Ross mine, near Gaffney, S. C., and at the Jones mine, 7 miles northeast of Kings Mountain.

Where sufficient water can be obtained and power developed, all of the soil, gravel, etc., can be readily washed down, often advantageously first through ditches cut into the ground and then into the sluice boxes, so that there is no necessity of handling the materials until the concentrates are taken out of the sluice boxes. As has been stated, however, in many sections of this tin belt water is rather scarce, so that a sufficient quantity could not be obtained for this purpose, and it would be necessary to excavate the gravels, soil, etc., and haul them to where they could be dumped on to the perforated plates above the sluice boxes. This is what is now being done at both the Ross and Jones mines. At the former mine, however, the stream which flows at the foot of the hill is being dammed, and it is expected that a sufficient quantity of water can be stored up so that the whole hillside can be washed down without the necessity of hauling any of the material by wagon.

At the Jones mine water is still more scarce, and it is questionable whether a sufficient supply can be developed to hydraulic the hillsides. The ore in the vein at this mine is composed largely of quartz and mica, making a rather solid ore, which would have to be crushed before it could be concentrated. It crushes, however, very easily, and the tin readily frees itself from the gangue minerals.

At the Ross mine, on the other hand, where the vein is composed largely of kaolinized feldspar, it is readily broken down by water and requires no crushing.

All of the ore that cannot be washed down by hydraulicing processes is being mined by means of open cuts, pits, etc.

VEIN TIN ORE.

In treating the ore, where it occurs in a hard vein formation, it will first be necessary to crush it. On account, however, of the position of the tin in the vein, it will often be found that the ore can readily be hand-sorted as it comes from the mine, so that a considerable concentration can be made before the ore goes to the crusher, thus eliminating a great deal of waste material which otherwise would have to pass through this machine. The ore will crush very readily, and as a rule the cassiterite separates itself very easily from the gangue minerals, so that it is not necessary to crush the ore to very fine sizes. This can be accomplished either by running the ore through

a crusher and stamp mill and then passing the crushed product over Wilfley concentrating tables or by using a crusher and rolls and then running the crushed ore on to concentrated tables or on to ordinary jigs. In this way a very pure tin concentrate will be obtained, which will be freer from accessory minerals than that obtained from the placer deposits; for, as has been stated above, there are but very few minerals directly associated with the tin in the veins.

ECONOMIC VALUE OF THE CAROLINA TIN DEPOSITS.

The practical question that is at once raised regarding the occurrence of tin in the Carolinas is whether it will pay to work these deposits. There is no question whatever but that the alluvial deposits, like those at the Ross mine, will pay to work and give large returns on the amount spent in obtaining the tin concentrates. These deposits, however, are carrying from 12 to 40 or more pounds of cassiterite to the cubic yard. A large proportion, however, of the alluvial deposits throughout the whole belt will not carry more than a few pounds of cassiterite to the cubic yard, which would mean from 1 to 4 pounds of metallic tin. With tin valued at 25c., this would mean that the alluvial deposits would be worth from 25c. to $1 per cubic yard, and would very probably pay to work, if operated on a large scale, even when the cost of pumping water is taken into consideration, especially as the conditions for mining in the Carolinas are so favorable. Sluicing could be carried on with but few days of interruption throughout the entire year; and then labor is cheap, miners receiving from 75c. to $1.25 per day. Cord wood can be delivered for $1.50 to not over $2 per cord, and consisting of the best firewood, being a mixture of oak and pine. Timber and other supplies can also be obtained at very reasonable prices. The greatest expense will be the installation of the pumping plant and storing of water for hydraulicing.

Regarding the economic value of the tin ore occurring in the veins, this is a little more problematic. Still if the veins contain but one per cent. of metallic tin, this would make an ore worth $5 per ton and would undoubtedly make a profitable proposition, if the deposits can be shown to contain a sufficient quantity of ore, so that a plant could be installed that would be capable of treating about 500 tons of ore

daily. Of course before there should be any expenditure made to equip any of the properties with machinery for treating the ore on a large scale further explorations and tests should be made.

EXTRACTION OF TIN FROM ITS ORES.

REDUCTION OF THE ORES.

As the ore of tin consists simply of the one mineral, cassiterite, the stannic oxide, the metallurgy of this metal is comparatively simple, the reactions involved in the reduction of these ores being theoretically of the simplest character, but practically they are complicated by certain mechanical as well as chemical reactions that enter in. These are due to the high temperature of the reduction, which causes also a reduction of the oxides of other metals that are invariably present with the tin, which are apt to alloy with it, this being especiallly true of the iron. Then again, the furnace in which the tin ore is reduced must be capable of resisting the high temperatures required for this reaction, and if the furnace lining is an acid one, consisting of silica or silicates, there is produced a certain amount of tin silicate; and if a basic lining of magnesia or lime is used there is a certain amount of stannates formed. The silica or acid linings are more generally used, as most of the tin ores contain a certain amount of silica or silicates. Thus, while the ore is readily reduced to metallic tin, only a very small amount is obtained as a nearly pure tin. There is a great deal left in the slag and as "hard head," so that it is necessary to re-work the slags and also refine practically all of the tin obtained by the first reduction. Mr. Henry Louis* has given a thorough and exhaustive description of the metallurgy of tin, and in this paper he divides the reduction of this metal into three stages, as follows:

"(a) Reduction or tin smelting proper; (b) refining the impure tin; (c) cleaning the slags. Each of these stages may be performed in more than one way, and to their various combinations the different local modifications of tin smelting are due.

"Tin smelting proper is conducted either in shaft furnaces or in reverberatories. The former method requires as an essential condition a supply of very pure fuel—such as wood charcoal—in sufficient

* Mineral Industry, Vol. V, 1896, p. 533.

quantity and at a reasonable price, and is best suited to ores in not too fine a state of division and of a high degree of purity. The latter method requires a fuel capable of giving a hot flame and can be applied to less pure ores and to ore that has been very finely crushed. It requires, however, a good supply of refractory material and demands a higher degree of technical skill than the former process."

Thus in the early reduction of tin ores the use of the shaft furnaces was the original process, and even at the present time it is still used very extensively in the tin districts of the far east. In Cornwall the reverberatory furnaces are used and coal is the fuel, and they are capable of treating the finely crushed and more impure ores that are now being obtained. Whichever method is used, it is necessary to clean the slags which contain tin, both mechanically mixed and chemically combined in the form of silicates. The metallic tin in the slag can readily be separated either by fusing the slag and allowing the molten tin to separate out from the slag, or on account of the high specific gravity of the tin, it can be readily separated by crushing and washing the slag.

REFINING THE CRUDE TIN.

The tin that is first obtained has to be refined, and there are two different methods which are being employed at the present time, known as (1) "liquation" and (2) as boiling or "tossing." Mr. Louis* describes these processes as follows:

"In liquation advantage is taken of the low melting point of tin; impure tin is heated on the incline bed of a furnace to a temperature but little above the melting point of tin; comparatively pure tin trickles down and is received in a large basin or 'float,' in which it is kept in a molten state. The residue on the bed of the furnace consists of the difficultly fusible alloy of tin and iron, known as 'hard head,' which generally contains sulphur, arsenic, copper, and other impurities. Liquation will obviously not remove readily fusible impurities, such as lead and bismuth, and the tin is purified from these by boiling or 'tossing.' The former operation consists in thrusting a billet of wood—apple-wood or cherry-wood being preferred—below the surface of the molten tin in the float; steam is evolved, together with permanent gases produced by the destructive distillation of the

*Ibid.

wood, and their escape throws the tin into violent agitation, projecting portions that splash back into the float, so that a large surface of tin in the molten state is exposed to the oxidizing action of the atmosphere. In tossing, the same result is attained by taking out the molten tin by ladlefuls and pouring it back into the float from a height of 2 or 3 feet. By either method oxidation is promoted and the impurities in the tin, together with a certain quantity of the tin itself, are oxidized and form a pulverulent scum on the surface of the float, whence they can be skimmed off from time to time. The metal is allowed to stand for some hours before it is finally ladled out and cast into molds, so that the impure metal may settle down to the bottom of the float, tin being, as already stated, specifically lighter than most of the impurities that are apt to impair its valuable quantities."

THE METAL TIN.

Tin is a rather heavy metal of a pure white to slightly bluish color, having a specific gravity of 7.29 to 7.3; though the ordinary commercial tin is 7.5, being due to the impurities it contains, which are in most cases of metals that are heavier than the tin. It is nearly permanent in the air, being affected but very little by exposure to the air, even in the presence of moisture at ordinary temperatures. When heated in the air at a rather low temperature it is gradually converted into the stannic oxide, which is of a yellow-white color and is known as putty powder. When heated to a temperature of between 1,600 to 1,800° C., if exposed to the air, it burns with a white flame. If, however, it is heated to this same temperature out of contact with the air the metal boils. The metal point of tin is variously given as from 227° to 233° C. In this condition it forms a very mobile fluid. Tin is a very highly malleable metal, less ductile, its tensile strength being low. The usual impurities found in commercial tin are iron, arsenic, sulphur, antimony, bismuth, and copper, the effect of most of these being to diminish the ductility of the tin. They also cause the metal to have a duller lustre and grayer color. It alloys readily with many of the other metals, and considerable use is made of this property of tin in the arts. The readiness with which tin alloys with iron affects to some extent the extraction of the tin from its ores. Such alloys of tin and iron are obtained in the beds of the furnace

during the smelting operations and is known as "hard head," consisting of a dark gray, irregularly granular crystalline mass, which is brittle and consists of more or less metallic tin intermingled with definite alloys of tin and iron.

USES OF TIN.

The value of tin in the arts was recognized long before the beginning of the Christian Era,* and it is believed that 450 years before Christ, Herodotus alludes to the tin Islands of Brittany, from which the tin was obtained. The Phœnicians and Greeks also traded with Cornwall in the purchase of tin. There have been many and various uses devised for tin, of which the greatest is in the manufacture of tin plate. There has been an enormous increase during the past few years in the use of tin for this purpose. The tin plate manufacture consists of the coating or tinning of the other metals, especially iron, thus making what is commonly known as sheet or plate tin, used for roofing, tin-ware, boxes, canning, etc. This use of tin has been handed down from the time of the Romans, who used copper vessels coated with tin, though not commonly, and, as stated by Pliny, these tin articles could scarcely be distinguished from the silver ones, and, as far as we can learn, they used in their manufacture practically the same process that is being employed at the present time, namely, of immersing the copper vessel in a pot of molten tin. This metal is also used in the silvering of mirrors, which is accomplished by covering glass with an amalgam of tin and mercury. Tin foil also calls for considerable tin, but at the present time a great deal of the tin foil on the market consists of plates of lead coated with tin, which have been rolled out to the required thinness. Solder, which is used so extensively, is an alloy of tin and lead, but often containing a small percentage of antimony. There are a number of alloys of tin with copper, the two principal ones being bell metal, which contains from 65 to 80 per cent. copper and 20 to 35 per cent. tin, with a small fraction of a per cent. of antimony, and bronze, which contains 93 per cent. of copper and 10 per cent. of tin.

Tin oxide is also made from metallic tin, which, on account of its hardness, is employed as a polishing powder, and is used, especially

* J. D. Dana, Manual of Min. and Lithology, 3rd Edition, 1880, p. 161.

in the form of a paste, for sharpening fine cutting instruments. This oxide is also used to some extent in the preparation of enamels. The chlorides of tin (stannic and stannous chloride) are used in the preparation of many colors and also as mordants in dyeing. The bisulphide of tin, which has a golden lustre, is used for ornamental painting.

VALUE OF TIN.

There is considerable fluctuation in the value of tin, owing to the uncertainty of the supply and to the fact that the operators of the mines in the Malay Peninsula are beginning to realize their power to control, to some extent at least, the market, and have, therefore, been holding back their ore.

The variation in the value of tin per pound is shown in the following table, which gives the average value for each month in 1902 and 1903:

MONTHLY AVERAGE PRICES OF TIN IN NEW YORK.*

Month.	Price per Pound.	
	1902.	1903.
	cents.	cents.
January	23.54	28.33
February	24.07	29.43
March	26.32	30.15
April	27.77	29.81
May	29.85	29.51
June	29.36	28.34
July	28.38	27.68
August	28.23	28.29
September	26.60	26.77
October	26.07	25.92
November	25.68	25.42
December	25.68	27.41
Year	26.79	28.09

* Eng. and Min. Jour., Jan. 7, 1904, p. 19.

As is seen from the above table, there was an increase of about one and one-quarter cents per pound in the average price for the year 1903 over that of 1902.

PRODUCTION OF TIN.

PRODUCTION OF TIN FROM THE CAROLINAS.

The first production of tin ore from the Carolina belt was during the summer and fall of 1903, and was from the Ross mine, the shipment consisting of 38,471 pounds of tin concentrates, which were sent to England for treatment. There has also been a small production at the Jones mine during the development work, but none of this has as yet been shipped.

WORLD'S PRODUCTION OF TIN.

At the present time none of the tin used in the United States is produced in this country, but it is all obtained from foreign sources. The fact that about 43 per cent. of the world's production of tin is consumed in the United States emphasizes the importance of discovering a source of supply of this metal that can be controlled by this country. It is hard to obtain accurate figures regarding the total production of tin in the world, for the reason that in some countries there is little or none exported, and no reliable statistics are collected in these countries of their mineral production. For instance, in China there is at the present time practically no exportation of tin, although occasionally exports have been made of Yunan tin. The production of tin in China has been variously estimated, and has been put as high as 20,000 tons per annum; but, while these figures are undoubtedly too high, no closer figure can be given which would accurately represent the production. There is also a certain quantity of tin produced each year in Mexico, a very small part of which is exported to the United States; but as no accurate record is kept of the quantity obtained, the total can only be approximately represented in the world's total production. Then again, the statistics regarding the Bolivian production of tin that is used in that country are difficult to obtain, although accurate statistics are available of the quantity exported. In the following table there is given an approximate idea of the production of tin by countries during the past seven years, which shows the growth of the tin industry as well as the yearly production of each of these countries:

PRODUCTION OF TIN IN THE WORLD (LONG TONS).*a*

COUNTRY.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
Malay States	44, 914	45, 901	45, 944	47, 855	52, 989	53, 756	54, 797
Banka and Billiton	14, 800	14, 380	14, 123	16, 640	19, 365	18, 765	20, 060
Bolivia	5, 506	4, 464	4, 753	6, 937	9, 670	10, 150	9, 500
Cornwall, England	4, 453	4, 648	4, 013	4, 268	4, 125	3, 950	4, 150
Australia	3, 466	2, 420	3, 337	3, 178	3, 276	3, 206	4, 991
Miscellaneous†	360	655	970	760	450	350	395
Total‡	73, 499	72, 468	73, 140	79, 638	89, 875	90, 177	93, 893

a Mineral Industry 1902, p. 586; Eng. and Min. Jour., Jan. 7, 1904, p. 18.

† Includes production in Austria, Germany, Japan, Mexico; and in 1903 from South Carolina.

‡ This does not include the production of China.

As is seen from the above table, there has been an increase in the total amount of tin produced each year, but this is still short of the demand for this metal, as indicated by the great decrease in the stocks of tin that have been kept on hand in the various countries. The production of the Malay Peninsula, the largest producers, has increased about 22 per cent. during the past 7 years; while that of the Islands of Banka and Billiton, the second largest producers, has increased about 35 per cent.; and Bolivia, the third largest producer, has increased its production about 84 per cent. England's production has declined slightly, and the Australian production, which is fifth, has increased about 44 per cent.

The production of tin during 1903 was consumed approximately as follows: 43 per cent. by the United States; 28 per cent. by Great Britain; 22 per cent. by other European countries; and 7 per cent. by India and China. This, of course, does not include the small productions used in Mexico, Japan, Bolivia, etc.

IMPORTS OF TIN INTO THE UNITED STATES.

The tin consumed in the United States for the year ending June 30, 1903, was obtained, according to the report of the Bureau of Statistics, from the countries named in the following table, which also gives the quantity and value obtained from each:

IMPORTS OF TIN INTO THE UNITED STATES FOR THE YEAR ENDING JUNE 30, 1903.

Country.	Tin in Bars, Blocks, Pigs, Grain or Granulated.	
	Quantity. Short Tons.	Value.
Malay Peninsula	23, 592	$12, 715, 875
England	17, 591	9, 374, 563
Netherlands	1, 726	944, 304
Other European Countries	853	441, 114
Australia	224	119, 851
Japan†	42½	23, 095
Total	44, 028½	$23, 618, 802

†Includes a very small amount from China and Mexico.

It will be noticed in the above table that the amount quoted as having been imported from Great Britain is nearly four times that produced in England. This is due to the fact that a considerable portion of the tin produced in the Malay Peninsula is shipped to Great Britain from Singapore, and is in turn imported from there into the United States. Thus it will be seen that the greater part of the tin consumed in the United States is mined in the Malay Peninsula. That imported from the Netherlands represents tin that was obtained from the Islands of Banka and Billiton. Some of the tin imported from other European countries was obtained from Bolivia.

SOURCES OF SUPPLY OF TIN.

The main source of supply of tin is from the Malay States, which furnish over one-half of the total amount consumed in the world. To increase this supply to any great extent is almost out of the question, at least for the present, on account of the necessity of making such decided changes in the method of mining, which is well-nigh impossible, as most of this mining is in the hands of the Chinese. The same is true of the Islands of Banka and Billiton, which produce one-fifth of all the tin used in the world. The deposits in the Chinese Empire are in so remote a part of the country that little is known

of their extent or of their yearly production; but it is, however, at the present time practically all consumed in China. The Bolivian mines, which now furnish about one-tenth of the world's supply of tin, have been constantly increasing their production during the past ten years, and during this time they have nearly doubled their output per year. On the other hand, the production from Tasmania and England has been decreasing.

Although there has been an increase in the total amount of tin produced each year, it does not equal the demand, as shown in the table given below.

In order to illustrate the increase in the demand for this metal, which is not supplied by the yearly production, there is given in the following table the accumulated stocks of tin that were on hand at the end of each of the past seven years:

STOCKS OF TIN IN ENGLAND, AMERICA AND HOLLAND (LONG TONS).*a*

Stocks on Hand December 31.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
Stock of foreign in London	18,097	15,146	8,110	5,486	4,286	5,114	4,557
Foreign landing in London	1,174	673	165	1,212	1,297	689	712
Malay Peninsula afloat for London, including wire advices	2,792	2,500	1,050	2,900	3,835	2,780	2,845
Australian afloat for London, including wire advices	525	600	400	450	350	522	518
Banka on warrants in Holland	1,616	2,877	2,228	1,160	837	696	644
Billiton in Holland	1,638	1,328	1,036	470	330	329	60
Billiton afloat for Holland	1,742	1,193	1,322	1,050	350	440	333
Malay Peninsula stock in Holland	789	377	454	100	60	30	------
Malay Peninsula afloat for Holland	950	100	215	------	------	------	------
Malay Peninsula afloat for Continent	650	600	560	450	590	873	650
Bolivian in Liverpool	250	710	300	550	495	846	184
Total stocks	30,223	26,104	15,840	13,828	12,430	12,319	10,503
Estimated stock in America and quantity floating	3,925	4,500	4,300	2,500	2,600	6,050	4,450
Grand totals	34,148	30,604	20,140	16,328	15,030	18,369	14,953
Trading Co.'s reserves of unsold Banka stock in Holland	5,953	4,333	3,213	4,353	5,347	7,251	1,466

a From the annual metal circulars of William Sargant & Co., A. Strauss & Co., and Min. Industry, Vol. XI, 1903, p. 587.

As is seen from the above table, there was only one year, 1901, that showed any increase in the accumulated stock of tin at the end of the year over that of the previous year. This was an increase of 3,339 tons of tin in the accumulated stock, but at the end of 1902 the stock on hand had decreased to 14,953 tons of accumulated tin, and at the end of 1903 it was still lower. The accumulated stocks of tin in the United States, which had ranged from about 3,500 to 7,200 tons during the years 1896 to 1901 were reduced during 1902 to less than 1,500 tons.

These figures illustrate emphatically the need of new sources of supply of tin, and why new deposits like those in the Carolinas and Alaska should be thoroughly investigated.

One result of this scarcity in the supply of tin and consequently the high valuation of this metal has been the utilization of old tin cans and other scrap tin as a source of the metal. The amount of tin that is recovered each year in this way, while not large, is steadily increasing, and it is becoming an industry of some considerable importance. There are now a number of companies that have been organized for this purpose, of which the more important ones are the Vulcan Detinning Company, whose plants are at Sewaren, N. J., and Streator, Ill.; the Ammonia Company of Philadelphia, and the Johnson & Jennings Company of Cleveland and Chicago. In recovering the tin from the scrap, this latter is digested in an alkaline solution and the tin electrolytically precipitated therefrom in the form of a powder, which averages 80 per cent. metal.* The sheet iron that remains, which contains a little tin, is melted and cast into window-sash weights and other objects where the small percentage of tin in the iron is a desirable feature.

* Min. Ind., 1902, p. 585.

PUBLICATIONS OF THE NORTH CAROLINA GEOLOGICAL SURVEY.

BULLETINS.

1. Iron Ores of North Carolina, by Henry B. C. Nitze, 1893. 8°, 239 pp., 20 pl., and map. *Postage 10 cents.*

2. Building Stone in North Carolina, by Joseph A. Holmes, George P. Merrill and T. L. Watson. *Postage 10 cents.*

3. Gold Deposits in North Carolina, by Henry B. C. Nitze and George B. Hanna, 1896. 8°, 196 pp., 14 pl., and map. *Out of print.*

4. Road Material and Road Construction in North Carolina, by J. A. Holmes and William Cain, 1893. 8°, 88 pp. *Out of print.*

5. The Forests, Forest Lands and Forest Products of Eastern North Carolina, by W. W. Ashe, 1894, 8°, 128 pp., 5 pl. *Out of print.*

6. The Timber Trees of North Carolina, by Gifford Pinchot and W. W. Ashe, 1897. 8°, 227 pp., 22 pl. *Postage 10 cents.*

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8. Water-powers in North Carolina, by George F. Swain, Joseph H. Holmes and E. W. Myers, 1899. 8°, 362 pp., 16 pl. *Postage 16 cents.*

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ECONOMIC PAPERS.

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